SCREENING OF GENETICALLY DIVERSIFIED BRASSICA GENOTYPES AGAINST APHIDS

By

Mansoor Ahmad

A thesis submitted to Khyber Pakhtunkhwa Agricultural University Peshawar in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY (Ph.D) IN AGRICULTURE (ENTOMOLOGY)

DEPARTMENT OF ENTOMOLOGY
FACULTY OF CROP PROTECTION SCIENCES
KHYBER PAKHTUNKHWA AGRICULTURAL UNIVERSITY
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DEDICATION

To my mother—and all mothers—for their constant prayers and efforts to educate a generation who will make a difference in the world. We are deeply indebted to them.

May Allah always grant them His loving grace.

To the children, those who are roused from their beds while still dark to bear the daily grind of waiting for the crowded bus to school. Through the heat and the cold, they persevere—because they dream of a better life.

May Allah keep watch over them and bless them all.

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December, 2011 (Mansoor Ahmad)

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ABSTRACT

Screening of Brassica oilseeds genotypes belonging to four Brassica species including *Brassica napus*, *Brassica Juncea*, *Brassica campestris* and *Brassica carinata* was carried out under field and screenhouse conditions during crop season 2006/07 and 2007/08. Under field conditions average aphid's density per plant was at peak during the 2nd and 3rd weak of February. Although non of the 12 genotypes was completely free of aphid attack under field conditions, nonetheless based on aphid density, Vangard with lowest aphids population (12.84 aphids/plant) was found to carry some resistance against aphids attack whereas genotype Legend with highest aphid density (37.94 aphids/plant) was on the other extreme. With respect to yield and its components, highest values for seed yield (2386 kg/ha), plant height (214.3cm) and number of branches/plant (19.20) were recorded in Peela Raya, whereas maximum 1000 grain weight (4.80g), siliqua length (8.31cm) and seed/siliqua (23.57 seed) were found in Westar, Ganyou-5, and Oscar, respectively. Highest oil, protein, oleic acid and moisture contents were found in Oscar (52.10%), T-16-401 (25.12%) and Oscar (7.09%) and lowest percentage for glucosinolates, linolenic acid and erucic acid were found in Rainbow (67.35 µm g^{-1}), Ganyou-5 (8.78) and Crusher (36.44), respectively. Under screen-house conditions, with artificial infestation of 0, 5, 10 and 15 aphids/plant at flower-bud initiation stage in 12 Brassica genotypes, overall seed yield losses ranged from 11.08 to 75.88% from aphid's density of 37.33 and 132.7/plant in T-16-401 and Vangard, respectively. Lowest average percent losses in seed yield, straw yield, plant height and branches, were recorded in T-16-401 (23.18), Ganyou-5 (20.35), Peela Raya (25.32) and T-16-401 (6.25) with average aphid's density/plant of 59.00, 37.83, 65.72 and 59.00. Losses in both, siliquae mr^{-1} and leaves, were found in Westar (16.24%) and (7.21) with average aphids density/plant of 108.2. Highest average percent losses in Brassica oil and moisture contents were recorded in Oscar (5.90), and T-16-40 (21.27) with aphids density of 113.9 and 59.00 per plant, while highest percent gains in protein, glucosinolates, oleic acid, linolenic acid and erucic acid were recorded in Oscar (24.57), Rainbow (37.07), T-16-401 (19.82), Westar (13.93) and Legend (31.38) with aphid's density of 113.9, 138.9, 59.00, 108.2 and 114.8 per plant. Among the *Brassica napus* group the lowest yield losses (16.25%) were recorded in Legend from 69.67 aphids/ plant. Overall, among the 12 genotypes Vangard, Crusher and Legend were the best. Based on comparatively better performance against aphids attack and making minimum compromise on yield and yield components and exhibiting increased oil recovery, the Vangard, Crusher and Legend were found best among the genotypes included in the study.

CHAPTER-I
INTRODUCTION

1.1 IMPORTANCE OF BRASSICA

Pakistan is constantly scarce in production of edible oil and meets its requirements through import from other countries which cost an enormous amount of foreign exchange. Its import bill is continuously the second largest after petroleum and constitutes the single largest expenditure on any of the imported food items. During 2009-2010, Pakistan imported 1.246 million tones of edible oil that cost 77.78 billion rupees (MINFA, 2010). An additional amount of Rs. 24.368 billion was spent on the import of seed by solvent industry for crushing during the said period, thus the total import bill was further raised.

The shortage of edible oil in the country is attributed mainly to the population growth, increase in the per capita consumption, stagnant local production of oilseeds and non-availability of high yielding oilseed cultivars. Expanding urbanization, increased per capita income, and high cost as well as meager availability of animal fats have concomitantly signified the problem (Swati, 2005).

Oilseeds are mainly produced for vegetable oil and increasingly for making biodiesel, and also for their meal for animal feed. They are grown widely across the world in both temperate, warm temperate and tropical regions. World trade in oilseeds is around 90 Mts of which 10 Mts of vegetable oil from oilseeds (MINFA, 2009). Brassica oilseed crop ranks third worldwide on the basis of production and area harvested after soybean and cotton. It is one of the big sources of vegetable oil of the world (FAOSTAT, 2004). Brassica is the second most important source of vegetable oil after cottonseed in Pakistan. In Pakistan total area under brassica cultivation is more than over 244.9 thousand hectares and its annual production is 198.9 thousand tones (MINFA, 2009). The national yield of brassica is 812 Kgs per hectare.

During 2008-09, 57.91 million metric tones of rapeseed were produced from an area of 31.11 million hectare throughout the world with yield 1.86 metric tons per hectare. The average yield of rapeseed per hectare for United States, Australia and Canada is 1.64, 1.09 and 1.95 metric tones per hectare

respectively (USDA, 2011). National yield of rapeseed in Pakistan is much less than that of developed countries like United States, Australia and Canada having an average yield of 1.56 metric tones ha^{-1}.

In Khyber Pakhtunkhwa (KP), rapeseed and mustard is grown on 17.7 thousand hectares with total production of 7.4 thousand tones. Its average yield is 418 kgs/hectare (MINFA, 2009), which is even less than the national average yield (i.e. 812 kgs $ha^{-1)}$, indicating a serious need to improve the yield at least to the level of national yield.

Rapeseed (*Brassica napus, B. campestris* and *B. juncea*) is used world wide to produce edible oil (Downey and Rakow, 1987). These crops can be successfully grown in various types of soils (French, 1977). Rapeseed-mustard "sarson" (*B. campestris*), "raya" (*B. juncea*) and "taramira" (*Eruca sativa*) are important species of Brassica group grown as oilseed crops in Pakistan. In the Indian sub-continent *B. campestris* is also one of the most important oil seed crop. These cruciferous species are extensively grown throughout the rain-fed areas of KP. It is known as having great yield potentials for semi arid conditions and is considered more drought tolerant and shattering resistant than *B. napus*. Due to its earlier maturity than *B. napus*, *B. campestris* escapes the attack of insect pests. *B. napus* (gobhi sarson) is rather recent and one of the most important species, its cultivation is restricted to some areas of Khyber Pakhtunkhwa and Punjab (PARC, 1991). In Pakistan brassica is grown mostly as a mixture crop with berseem for fodder. Other *Brassica* species, types and cultivars (i.e., *Brassica nigra*, *B. carinata*, *B. oleraceae*, *B. hirta* and *B. juncea*) are cultivated in different areas of Pakistan (Weiss, 1983).

In Pakistan, the important *Brassica* species grown as oilseed crops are sarson (*B. campestris)*, raya (*B. juncea*) and Taramira (*Eruca sativa*). These species are considered to be early maturing, drought tolerant and resistant to aphids but inferior in oil recovery and oil quality. The recently introduced *B. napus* (canola) is generally with lesser levels of glucosinolates and erucic acid, better in oil content and quality than rapeseed cultivars but is late maturing and susceptible to insects, particularly aphids (PARC, 1998).

In general, the yield of brassica oilseeds crops in Pakistan is much lower (812 kg/ha) than the average yield in developed countries (1560 kg/ha). The factors responsible for it have been identified as the lack of suitable genotypes and several a-biotic and biotic environmental stresses, the more important being insect pests, diseases, drought and frost (Swati, 2005; USDA, 2011).

A number of efforts have been undertaken to improve the rapeseed-canola cultivars to improve the quality, production and resistance against aphids. In this respect new genotypes and varieties have been evolved and tested in different parts of Pakistan. The new genotypes are better in quality, oil contents and vigor (Swati, 2005).

This huge edible oil expenditure can only be reduced by improving the domestic oilseed production and developing more local varieties that are resistant to insect pest and give more production.

1.2 IMPORTANCE OF APHIDS IN BRASSICA

A number of insect pests attack brassica crops, which result in poor growth and low yield of the crop. One of these important pests is aphids. Aphids multiply very rapidly under favourable conditions and form dense colonies on plants. Among the aphid species the mustard aphid, *Lipaphis erysimi* (Kaltenbach) is a severe pest of brassica in hot and humid areas of the world and is of major economic importance to brassica crops in Pakistan. The economic impact of aphid damage can be from 80% yield losses to complete crop failure, if attack comes at seedling stage (Amer et al. 2009; Singh & Bakhetia, 1987). In a field survey damage by aphids has been indicated as the biggest hesitation of farmers, planting these crops on large fields (MINFAL, 1995).

In Pakistan, winter oilseed brassica crops are attacked by *Lipaphis erysimi* (Kalt.) and to a lesser extent by *Brevicoryne brassica* (L.) and *Myzus persicae* (Sulz.). Aphids are the most important insect pests, causing 70-80% yield losses. Hamid and Ahmad, 1980, Rustamani et al*.,* 1998)

Three aphid species associated with brassica oilseeds are: *Lipaphis erysimi*, *Myzus persicae* and *Brevicoryne brassicae*. Among these, the cabbage aphid (*B. brassicae*) is most predominant on cabbage; cauliflower,

rape and turnip rape throughout the European and American countries (Weiss, 1983). The green peach aphid or potato aphid (*M. persicae*) is a well-known vector of several plant pathogens of worldwide occurrence and of great economic importance. It is of minor significance to cruciferous oilseeds. The mustard aphid (*L. erysimi*) though a cosmopolitan is of major economic consequences to brassica crops in the Indian sub-continent (Landin, 1982: Bakhetia & Ghorbandi, 1987).

Mustard Aphid (*Lipaphis erysimi*) (Kaltenbach) attacks several vegetable crops including: broccoli, cabbage, mustard cabbage, radish, tomato and zucchini. Aphids feed by sucking sap from their hosts. Large colonies can cause the plants to become deformed and the leaves curled, shriveled and yellowed (Metcalf and Flint, 1962). The turnip aphid can sometimes be found in large numbers on the undersides of outer open leaves or in the inflorescences (Blackman and Eastop, 1984). In severe infestations, both sides of leaves are infested (Yadav et. al. 1988). On cabbage, large populations can affect leaf size (Deshpande, 1937) and yield (Mohan et al. 1981). On mustard, these aphids prefer flowers to leaves (Singh et al. 1965). Aphids also produce honeydew. The honeydew serves as a medium on which a sooty fungus, called sooty mold, grows. Honeydew gives cabbage plants a dirty appearance that reduces their market value (Deshpande, 1937).

Aphids vector many plant diseases that cause greater losses than caused by direct feeding injury. This is often the greatest impact of an aphid infestation. The turnip aphid is a vector of about 10 non-persistent plant viruses, including cabbage black ring spot and mosaic diseases of cauliflower, radish and turnip (Blackman and Eastop, 1984). In non-persistent transmission the virus reproduces in the plant and aphids simply aid in dissemination of the virus and the infection process (Kawada and Murai, 1979).

Green Peach Aphid, *Myzus persicae* (Sulzer) has many host plants. On cole crops this species is usually present on the underside of the oldest leaves. It is common on seedlings, young plants and lower leaves of older plants (Flint, 1985). This aphid also vectors turnip Mosaic Virus. Both apterae (wingless) and alate (winged) aphids are able to transmit the virus but more transmissions are obtained with wingless forms (Toba, 1962).

Cabbage Aphid, *Brevicoryne brassicae* (Linnaeus) feeds on all cultivated and wild cruciferous plants. A native of Europe, the cabbage aphid is now found in many areas of the world. In the Tropics they are usually confined to higher altitudes. Colonies of these aphids are found on both lower and upper leaf surfaces and in leaf folds of developing heads, on leaf stalks, and on leaf axles. They are occasionally found on at the soil level. Aphids feed by sucking sap from their hosts. Infested seedlings may become stunted and distorted. Continued feeding on mature plants causes wilting, yellowing and stunting of the plants.

1 .3 RELATIVE RESISTANCE IN BRASSICA

One of the important methods to manage insect pest population is by developing plant varieties resistant to insects through various breeding procedures. Many insect-resistant crop varieties have played vital, integral roles in sustainable systems of agricultural production. Resistant varieties are nonpolluting; ecologically, biologically, and socially acceptable; and economically feasible as a means of pest control. Plant resistance to insects is defined as “the relative amount of heritable qualities possessed by the plant that influence ultimate degree of damage done by the insects”. Practically it is the performance of a cultivar to produce more of a good quality compared to other cultivars under similar insect population level (Painter, 1951). He also classified the nature of plant resistance into three types, that is, tolerance, antibiosis and non-preference. However, Beck (1965) recognized only biochemical and biophysical resistance to insect survival and suggested that tolerance was an agronomical attribute as it is influenced by the growth and vigor of the plant.

Farrell (1977) distinguished resistance into non-preference and antibiosis and further elaborated that factors of resistance are hereditary plant characters that effect resistance at certain phase or phases of insect and plant relationships. He suggested that resistance can take place at seven phases of insect-plant relationship viz. approach, arrest, oviposition, ingestion, assimilation, conversion and emigration. However, the definition and modalities of resistance explained by Painter (1951) are most comprehensive and widely accepted. The main modalities of genetic resistance are antixenosis, antibiosis

and tolerance. The term antixenosis means that the plant is refractory to guests, that is, the insects trying to colonize it (Kogan and Ortman, 1978). Antixenosis could be due to chemical or morphological. In chemical antixenosis when offered a choice of two or more alternative foods, phytophagous insects usually display a consistent pattern of preference. Inadequate hosts are often totally rejected and some insect species starve to death on a diet that lake the proper stimuli (Zwolferadn and Harris, 1971). Morphological antixenosis are grouped under the resistance mechanisms related to morphological or structural plant features that impair normal feeding or oviposition by insects, or which synergize to the action of other mortality factors. A direct effect of morphological characters on feeding is the inability of many insects to become established on plants. All kinds of adverse physiological effects on an insect body, temporary or permanent, as a consequence of ingestion of a plant are termed as antibiosis. Tolerance refers to the capacity of certain plants to repair injury or grow to produce an adequate yield despite supporting an insect population at a level capable of damaging a more susceptible host (Kogan, 1982).

Resistant varieties constitute the choicest tactic to control or suppress pest damage to crops to a worthwhile low level. They serve as an ideal component of an integrated pest management (IPM) program. They can be very cost effective, usually environmentally safe and involve no elaborate technology transfer to the farmers. Their effect is relatively stable. Resistant varieties are generally compatible with other pest management approaches including chemical, biological, cultural and other control methods. Normally adverse weather does not alter the action of resistant varieties as is often experienced with biological and chemical control. They provide an inherent mechanism of crop protection against the pest. Apparently, aphid resistant varieties of *Brassica* oilseeds would provide an ideal way for managing aphid menace (Swati, 2005). When a good resistant variety is available, a farmer may not have to change his desirable cultural practices or pay the costs of insecticides (Packard and Martin, 2010).

Many insect species especially that attack field crops which are grown on marginal land, cannot be economically controlled by the use of insecticides.

Therefore, it is necessary to seek other means for their management. The main aim of developing resistant varieties of *Brassica* is to reduce the use of chemical poisons because most of the insecticides are lipophilic in nature and are likely to be carried in oil and cake as well. Therefore, use of insecticides to control the mustard aphid can be very hazardous and damaging to the consumer's health and environment. Hence, insect resistant varieties constitute the choicest tactic to control or suppress pest damage; especially in countries like ours, where farm size is small and economic constraints and lack of technical know how limit the use of chemicals on these crops (Swati, 2005).

In Pakistan, efforts have been made to improve the rapeseed-canola cultivars to improve the quality, production and resistance against aphids. In this respect new genotypes and varieties have been evolved and tested in different parts of Pakistan. Also, brassica oilseed rape and mustard improvement program at the Institute of Biotechnology and Genetic Engineering (IBGE), KP Agricultural University, Peshawar, have developed oilseed rape material possessing improved oil content and quality as well as resistance to aphids (Swati, 2005).

1.4 LOSSES DUE TO APHIDS IN BRASSICA GENOTYPES

Brassica crop is attacked by a number of pests; amongst these aphids are more serious. The species of aphids i.e. cabbage aphid, *Brevicoryne brassicae* L., turnip aphid, *Lipaphis erysimi* Kalt. and green peach aphid *Myzus persicae* Sulz. are abundant and widely distributed (Rehman et al. 1987). *Brevicoryne brassicae* L. and turnip aphid *Lipaphis erysimi* Kalt are the most devastating pests of Canola (Amer et al. 2009). Of these, cabbage aphid is the most destructive to the members of Brassicaceae. Its attack, results in severe distortion of leaves and heavy losses to crops by forming large colonies on leaves, stems and inflorescence. Aphids infested plants show slow growth, which result in seed loss of 9-77%. Aphids also cause an 11% reduction is seed oil content (Kelm and Gadomski, 1995). In India aphids alone attribute 30-70% losses in rapeseed yield in different agro climatic conditions with an average loss of 52.2% (Roy and Baral, 2002). Under favorable circumstances, aphid's populations increase very rapidly by making dense colonies on all parts of plants. The economic impact of aphid damage can be from 80% yield losses

to complete crop failure, if attack comes at seedling stage (Singh and Bakhetia, 1987).

In Pakistan, cabbage aphid and mustard aphid are important pests of brassica (Aslam, 2005). Cabbage aphid causes 35-75% yield losses (Rohilla et al. 1987; Shoaib, 2003) and 6% losses in oil contents (Singh et al. 1987).

1.5 APHIDS POPULATION AND MORPHOLOGICAL AND BIOCHEMICAL QUALITY CHARACTERISTICS OF BRASSICA

Aphids are key pest of *Brassica* and cause damage to the crops of various intensities in different varieties, areas and climate. Morphological characteristics are important parameters that affect the overall preference for a variety, performance of a variety against insect pest and diseases attack, lodging resistance and yield performance. Morphological characteristics include plant height, primary branches, siliquae on main raceme, siliqua length, seeds per siliqua, 1000 Seeds weight and yield of the crop.

In oil seed crops, quality seed production is the major objective beside high yield. The quality of oil seed brassica depends on high percentage of oil, protein, oleic acid and low percentage of glucosinolate (GSL), linolenic acid and erucic acid. About 8.5% moisture content is also desirable for storage purpose (Khan et al. 2008). The *Brassica* species are grown on a large area of the world for edible oil production however their oil and cake is not fit for human and animal consumption as it contains high levels of erucic acid and sulphur compounds (glucosinolates). Especially, B. campestris, grown in Pakistan and India, contains 40-50% erucic acid and 80-160 µm g-1 of glucosinolate (Agnihotri and Kaushik, 1999), thus is restricting their use as edible oil crop. In addition the oil content of brassica oilseed meal contains well-balanced amino acid composition and about 40% protein. Theses amounts are lower than what is desired. Its use in human and animal nutrition is, however, limited due to its glucosinolate and erucic acid content. There is much scope of developing new varieties that contain low levels of glucosinolate and erucic acid. Therefore, there is great need to screen out breeding lines for lower levels of erucic acid (<2%) and glucosinolate (<30 µmg-1) with higher yield potential (Kaushik, 1998).

Linolenic acid is polyunsaturated fatty acid, which increases the high density lipoprotein in blood stream, which is beneficial for health due to its lowering effect on blood cholesterol level and reduces risk of cardiovascular diseases (Grundy, 1987). Glucosinolates are considered significant anti-nutritional compounds. The glucosinolates are natural plant products that contain sulphur and nitrogen and becoming more and more important as crop protectants, cancer prevention agents and flavour precursors (Graser et al. 2000). B. napus oil contains about 70% or more unsaturated fatty acids. However, the presence of certain toxic compounds, erucic acid and glucosinolates in the rapeseed oil lower its value (Khalil et al. 1989). Glucosinolates are the characteristic secondary plant compounds of brassica crops responsible for their odor and flavour but the primary function of glucosinolates in brassica plants is defense (Harborne, 1994).

Seed yield is complex character associated with many morphological characters such as number of branches per plant, number of siliquae per plant, number of seeds per siliqua, 1000-seeds-weight, plant height etc. Relation between seed yield and these characters is measured through correlation analysis. These characters may have positive or negative impact on seed yield. Efforts are underway to develop better rapeseed genotypes. Phenotypic correlation coefficients between seed yield and yield determining characters are prerequisite studies to help develop better genotypes. Just only few investigations include aphid's correlations with seed yield, yield and quality characters (Engqvist and Becker, 1993; Khan et al. 2006).

1.6 OBJECTIVES OF THE STUDY

A. To determine relative resistance against aphids among various indigenous and exotic *Brassica* genotypes under natural field conditions.

B. To determine relationship between aphids populations and morphological and quality characteristics of *Brassica* genotypes.

C. To determine relationship between aphids density and yield losses in different *Brassica* genotypes under screen house conditions.

CHAPTER-II
REVIEW OF LITURATURE

Kishaba and Manglitz (1965) measured the resistance to aphids on certain clones of alfalfa and clover. Aphids were offered a choice of leaves from resistant and susceptible clones and preference was determined by observing the aggregation of insects on plants after a period of time. In the beginning of the experiment the aphids were uniformly dispersed among all plants. After 20 hours three to four times more aphids had aggregated on the susceptible than on the resistant plants.

Singh et al. (1965) placed aphids on the inflorescence of test plants using special cellophane cages and studied the fecundity of 4 aphids in 15 days on *Eruca sativa* and on 14 varieties of Brassica. They classified the various cultivars, using the different fecundity groups. The fecundity was considered to be inversely related to resistance.

Free and Williams (1978) observed that most damaging pests of rape are pollen beetles, aphis, Mustard sawfly, pea leaf miner, flea beetles, seed pod weevils, hairy caterpillar and cabbage butterflies.

There are no outstanding examples of resistance attributed exclusively to the effects of chemical antixenosis. In field situations insects may feed or oviposit on a non-preferred host if a better one is not available. Perhaps for this reason resistant factors affecting behavioral mechanisms have been considered of secondary importance. This mechanism, however, may have a more subtle impact on pest populations and on partially non-preferred or even more preferred varieties (Kogen, 1982).

Patel and Pokharkar (1982) recorded *Hellula undalis*, *Erocidoloonia binolalis*, *Pieris brassicae*, *Agrotis ipsilon*, *Aulacophora fovicollis*, *Thrips tabaci* and *Bemisia tabaci* as pests on cruciferous crop.

Bakhetia and Ghorbandi 1987 determined yield losses and economic injury levels (EIL)/ economic thresholds (ETH) of Lipaphis erysimi on *Brassica*

juncea cv. RLM619 based on aphid population in field at Ludhiana (India). Six levels i.e. 10, 20-25, 50-60, 85-100, 180-200 and 300 aphids (nymphs + adults) per 10 cm shoot/plant and unsprayed control were maintained in randomized block design with 3 replications and 12 m2 plot. Five random shoots (one/plant) in a plot were observed at 5-7 days interval to record aphid population. Whenever the observed mean value reached the fixed level in a treatment, its plots were sprayed with dimethoate to control the aphid. Seed yield and related ancillary characters were also recorded. Avoidable yield losses were estimated up to 69%, with 1:13 cost/benefit ratio. Seed yield had negative correlation with mean and cumulative aphid population. Increase of one aphid decreased seed yielded by 4.98 kg/ha. The decrease in other parameters 0.8 pods/plant, 0.06 pods/main shoot, 0.01 seed/pod and 0.004 g/1000 seeds. The EIL and ETH were calculated as 85-100 aphids and 50-60 aphids per 10 cm shoot/plant, respectively for the flower-bud initiation stage of plant growth.

Brar et al. (1987) reported that the avoidable losses in yield of *Brassica* species caused by the mustard aphid varied from 28.8 to 52.5% in *B. juncea* cv. RLM 619 and 22.6 to 51.7% in B. napus cv. GSL 1. These estimates are quite alarming. Apparently the yield losses varied in different *Brassica* species from year to year and even in different fields at the same location. Also the variations in losses were quite evident in different insecticidal treatments for aphid control.

Brassica campestris has been largely cultivated all over the barani areas of NWFP. It is more tolerant to drought and resistant to shattering than B. napus and has great potentials for semi arid conditions. Due to early maturity than B. napus and it avoids the infestation of insect pest. B. napus (gobhi sarson) is rather new and grown as a seed crop in NWFP and parts of Punjab (PARC, 1991).

Aheer et al. (1993) tested thirteen wheat varieties/advance lines i.e. Kohinoor-83, Pak81, Punjab81, Sutlej86, V6236, V6300, V6521, V6550, V6566, V6632, V6751, V6916 and V7061 during 1988-89 to determine loss in grain yield caused by aphids (*Sitobion avenae*) F. and *Rhopalosiphum*

rufiabdominalis Sasaki. The experiment was carried out in two sets viz. sprayed and unsprayed. Perfekthion (dimethoate) at the rate of 741 ml/ha was sprayed in one set for four times at 10 days interval starting from February 18, 1989. Wheat lines differed significantly in response to aphid population and grain yield. There was no effect on grain yield. On an average, 7.19 aphids per tiller reduced 16.38% yield. Kohinoor83 was relatively susceptible with 22.53% grain yield loss and V-7061 was resistant with 10.76% yield loss. Correlation between grain yield loss and number of aphids causing yield loss was significant and negative. Wheat lines behaved differently with regard to aphid population and loss in grain yield.

Liu and Daozheng (1993) studied the influence of plant growth and yield losses caused by rape aphids. It was observed that the aphid's damage puts clear restrains on rape. With the aphid's number of aphids per 106 plants was over 5000 to 7000 the rate of plant height decreased by 41.6% to 50.4%, the leaf area by 69.5% to 71.3% and the number of branches per plant decreased by 51.1% to 76.3%. The rate of the yield losses were decreased by 73.0% to 96.3%.

Buntin and Raymer (1994) evaluated Canola, *Brassica napus* L., as a winter grain crop in the southeastern United States and he damage of insect pests was observed for three growing seasons in Georgia. The turnip aphid Lipaphis erysimi (Kaltenbach) and green peach aphid, Myzus persicae (Sulzer) caused direct injury to leaves and stems. Aphid injury reduced plant height and delayed plant development. Aphid injury reduced yield by 9.9, 30.4, and 34.8% in 3 years in the coastal plain region. In northern Georgia, yield losses caused by aphids were ≤2.0% and aphid injury reduced yield by 32.7% in one trial.

Cole (1997) investigated the relative importance of glucosinolates and the availability of free amino acids in the phloem to the feeding behavior and development of brassica aphid, cabbage aphid and peach potato aphid. Aphid development was measured on *Brassica* species and cultivated brassica varieties. Analysis of glucosinolates contents in the wild Brassica species showed significant differences in freeze dried leaves. Multiple regression

analysis showed a significant correlation (r = 0.83) between the rate of increase of *B. brassicae* and glucosinolate concentrations. The rate of increase of *M. persicae* was less correlated, though still significant (r = 0.5). Regression analysis also showed a correlation between phloem amino acid concentrations and the rate of increase of *B. brassicae* (r = 0.48) but not of *M. persicae*. Leaf water potential of the *Brassica* species showed no relationship with the rate of increase of either *B. brassicae* or *M. persicae*.

In India Mustard is an important oilseed crop and major source of edible oil for human consumption. The mustard aphid causes serious losses of yield in Mustard crops and reduces its marketable value. Increase in population beyond 9.45 aphids per plant; reduce the seed yield by 59.3 per cent with an economic injury level of 2.04 aphids/ plants with an index of 0.98 and infestation 37.4 per cent (Singh & Malik, 1989).

Mustard aphid is a serious insect pest of mustard and rape in hot and humid areas of the world. Aphid's population reaches to an extreme when the crop is about 70 days old. Spring and fall canola are attacked by this pest. It becomes serious before and during flowering stage; it damages flower buds, developing pods, and weakens the plants that cause up to 40 percent yield losses, if no control measures are adopted (Agarwala and Datta, 1999).

Amjad et al. (1999) studied the biology of turnip aphid on four Brassica varieties viz. *B. campestris*, *B. carinata*, *B. juncea* and *B. napus* (Westar). During the study he observed four nymphal instars. The shortest first stadium was found on *B. juncea* and the longest on *B. campestris*. The range of stadia for 2nd instars was 17-23 hours, 3rd instars 20-24 hours and 4th instars was 29-31 hours. The fecundity rate of aphids was the shortest on *B. campestris* while on the other varieties of Brassica it was similar. The pre and post-reproductive times ranged from 16-22 and 17-22 hours which was not significantly different from each other. Total developmental time of the aphids was about six days. *B. campestris* had significantly the highest reproduction rate followed by *B. napus*, *B. campestris*, *B. juncea* and *B. carinata*.

Siraj-ud-din (2000) recorded short horned grasshopper, Slanted head grasshopper, *Thrips tabaci* (Lind), *Lipaphis erysimi* (Kalt.), *Brevicoryne brassicae* (L), *Amrasca devastans* (Dist), Flea beetle and *Pieris brassicae* as insect pests of Brassicae crop at the experimental farm of the NWFP Agricultural University, Peshawar.

Vekaria and Patel (2000) studied relative resistance of forty promising Brassica and allied genotypes against mustard aphid, Lipaphis erysimi (Kaltenbach) in the field conditions at C.P. College of Agriculture, Sardar Krushinagar during rabi 1993-94 and 1994-95. None of the genotypes tested was found immune, however, five genotypes viz. GSL-1 (*B. napus*) PC-5 (*B. carinata*), T-27 (*Eruca sativa*), local genotype (*B. tournefortii*) and T-6342 were found resistant against mustard aphid. Mustard genotypes belonging to *B. campestris* group were found to be more susceptible to aphid than that of *B. Juncea*.

Resistance factors influencing feeding preferences have been identified in several cases. In Texas, Cruciferous crops, including cabbage, cauliflower, kale and broccoli are grown. Turnip aphid, green peach aphid and poplar petiole gall aphid are the most injurious and of economic importance (Liu et al. 2001).

Jatoi et al. (2002) conducted experiments on 22 varieties of B. napus to measure their relative resistance and susceptibility. At leaf stage two varieties i.e. Shiralee and Hybrid were found susceptible to turnip aphid, while the remaining cultivars were resistant or partially resistant. At flowering stage the varieties Hybrid, Crusher and Shiralee were found highly susceptible and at seed formation stage the cultivars Cyclone, Defender, Sponser and Shiralee were highly susceptible. At seed maturity stage Oscar and Cyclone were found susceptible while Shiralee was highly susceptible and the Cyclone, Hybrid, RNB-9604D, Defender and Oscar were intermediately susceptible. Relative resistance against turnip aphid was observed in the cultivars Sponser, Dunkled, Crusher, BULLT, KS-75, CON-III, BLN-977 and 19-H.

Roy and Baral (2002) stated that Mustard aphid; Lipaphis erysimi (Kalt.) plays an important role in determining the productivity of rapeseed-mustard. This pest alone attributes 30-70% losses in yield potential in different agro-climatic zones with a mean loss of 54.2% in India. They conducted an experiment to study the migratory nature of mustard aphid by trapping them in yellow color pan tray and their simultaneous growth and development on three different genotypes. The temperature during noon house is the predominant factor to govern the appearance of alate mustard aphid in rapeseed-mustard field. Step-wise regression analysis revealed that temperature and relative humidity played an important role for its development. The variety RW white flower glossy stem harbored minimum number of aphid in comparison to other two varieties B9 and T6342. The population reached a peak of 61.28aphids/10cm central twig during 6th standard week irrespective of varieties.

Al-Barzinjy et al. (2003) studied growth, yield components and canopy structure of four spring-type rape varieties including Cyclone, Gulle, Christa and Derby. Significant difference was found in the yield, oil and protein content between different varieties. The structure of the canopy showed that the siliquae were distributed evenly on the top most branches of the cultivar Cyclone, while in the varieties, Gulle and Christa, siliquae were mostly found on the main stem.

Abid et al. (2004) analyzed six cultivars of Canola (*Brassica napus*) oilseed (Bulbul, Dunkled, Rainbow, Oscar, Range and Range (local) for crude protein and crude oil contents by the standard methods of AOAC. Fatty acids and total glucosinolates contents were determined by Near Infrared Reflectance (NIR) spectroscopy. The data revealed significant (P= 0.05) variations among the six cultivars in all the chemical constituents. Bulbul and Rainbow were the oil rich cultivars, containing more than 47% crude oil in the oven-dried seed. Range and Range (local) canola cultivars contained the less amount of oil (43%). However, Range (local) was protein rich cultivar. Oleic acid content of the oil ranged from about 60 to 65% and that of linolenic acid from 9.6 to 11.5%. Oil of Oscar was better than all other cultivars with respect

to oleic acid content. However, Rainbow was the best cultivar in terms of linolenic acid content in the oil. Glucosinolates content of the six cultivars tested was less than 30 μ Mg^{-1}, which characterized these cultivars to be canola type Brassica. It was concluded that Bulbul and Rainbow were the best cultivars with respect to their oil content.

Farhatullah et al. (2004) conducted an experiment at Agricultural Research Station Mingora, on the genotypic performance of some advanced lines of rapeseed during 2000-2001. Twelve genotypes Hyola-308, Bullet, PB-4, 2II-98, Altex, Oscar, Dunkeld, Siren, PC-89, Altex, Shirallee, Altex, Candle, and Altex, PC-89 were studied. They recorded data on plant height, days to 50% flowering, leaf area, siliquae $plant^{-1}$, seeds $siliqua^{-1}$, 1000 seed weight, lodging (%), insect attack (%), seed yield kg ha^{-1}, oil contents and glucosinolate contents. The results showed significant differences for all characters except insect attack. Genotypes Hyola-308 and PC-89 were found to be the best. In case of hybrid Altex and Candle performed well for leaf area. The hybrid Altex x PC-89 was susceptible to lodging and insect attack and also gave the maximum glucosinolate contents (71.70). The genotype Altex was resistant to lodging and gave desirable amount of glucosinolate contents (29.67). The genotypes, Hyola-308, Altex, PC-89 and Altex and Shirallee, are therefore recommended for national uniformity trials.

Malik et al. (2004) carried out studies to assess the influence of different levels of sulphur fertilization (0, 25, 50, 75, 100, 125 & 150 kg ha^{-1}). The experiment was laid out in randomized complete block design with three replications and a net plot size of 1.8m x 5m. Data on growth and yield of canola were recorded by using the standard procedures. The results revealed that the highest seed yield (3725 kg ha^{-1}) was obtained in T4 with 100 kg ha^{-1} S which was however, at par with treatment where 125 kg S ha^{-1} was applied. While minimum seed yield (2870 kg ha^{-1}) was recorded in case of control i.e. with no S. Oil content progressively increased with increase of S level with highest (45.10%) with an S level of 150 kg ha^{-1}. But a perusal of economic analysis showed that T4 i.e. application of 100 kg ha^{-1} would be more economical than all other treatments.

Patel et al. (2004) reported *Lipaphis erysimi* Kalt. as one of the devastating pests in realizing the potential productivity of *Brassica juncea.* They carried out an experiment to assess the yield losses in mustard due to mustard aphids grown in different thermal environments under protected and unprotected conditions. To provide different thermal environments the crop was sown on 5 dates i.e. 08, 18 and 28 November and 08 and 18 December during winter seasons of 1995-96, 1996-97 and 1997-98. It was observed that yield attributes and yield of mustard was significantly decreased in delayed sowing even under protected conditions. On an average maximum seed yield of 1409 kg/ha was harvested when the crop was sown on 08 November under protected condition, while only 279 kg/ha seed yield was recorded under unprotected condition. Similarly the yield attributes and yields drastically reduced under unprotected condition as compared to protected one in all the thermal environments. On the mean basis 80.6, 81.4, 95.2 and 97.6 percent yield loss was observed under unprotected condition as compared to protected condition in 08, 18, 28 November and 08 and 18 December sowing, respectively. It was also observed that the critical period of mustard exposure to aphids was found to be the 3rd week after aphid appearance when the crop was in flowering stage and hence the control measures have to be initiated before flowering.

Sarwar et al. (2004) tested 12 canola genotypes under field conditions against aphid's infestation. To determine genotypic response on different genotypes, aphids' density and seeds yield obtained were recorded. Different genotypes revealed variable response to various aphids' densities. Lowest number aphids (44.92 per plant) were recorded in Rainbow and maximum (130.6 aphids per plant) in CON. III. Best yield (3330.0 kg/ha) was obtained in genotype Rainbow while the least yield (1720.0 kg/ha) in genotype Hyola-401.

Aslam et al. (2005) tested 10 canola varieties in the field. They observed population of aphids on different sampling dates and it was non-significantly different on all the tested varieties of Brassica napus. None of the variety was completely free from aphid's infestation. Maximum mean aphid population was recorded on con-I (57.8aphids), followed by Oscar (55.9 aphids), Con-III (50.5 aphids), Dunkeld

(48.9aphids), Shiralee (45.5 aphids), Westar (41.9 aphids), Con-II (41.6 aphids), Rainbow (36.9 aphids) and Abasin (35.7 aphids). K-S-75 was found to have minimum aphid population (30.7 aphids/ plant) and therefore was termed as relatively resistance compared to other varieties due to showing less aphid population.

Khan and Begum (2005) studied population of aphid on canola and observed that aphid started increasing from during 4th week of January and reached to the peak in 3rd week of February. An average of 2.91 aphids/leaf were found on Hyola, 2.24 on Zafar, 3.13 on Rainbow, 3.03 on Bulbul, 2.92 on Range and 5.96 on Dunkled. The data showed that none of the varieties was resistant/ tolerant to the attack of aphids. Results on different agronomical characteristics in different varieties showed that Bulbul variety was the tallest, Range produced more (18.87) sub-branches, while Hyola produced (19.80) sub- branches. Maximum No. of 447.3 and 681.9 siliquae/plant was recorded in Dunkled and Zafar varieties, respectively. Maximum seeds/siliqua (23.3) was recorded in Dunkled, while 26.23 seeds/ siliqua were noted in Bulbul variety. Maximum thousand seeds weight (2.91 g) was recorded in Hyola, while 3.71g was noted in Range variety. Rainbow variety produced maximum yield/plot.

Cornell University (2006) used plant genetics and molecular biology and demonstrated that glucosinolates breakdown products are toxic to *Myzus persicae*. Evidence indicated that in dole glucosinolates are important for plant defense: a) aphids on Arabidopsis mutants with increased glucosinolate levels produce fewer progeny; b) purified indole glucosinolates are aphid-repellent in an artificial diet; and c) purified glucosinolates added exogenously to detach Arabidopsis leaves increase insect resistance.

Khan et al. (2006) studied correlation of quantitative traits relating to yield and quality in eleven accessions of *B. napus*, along with DGL as a standard variety. Wide range of genetic variation existed among all the characters under study except 1000-seeds weight. Seed yield per plant was positively and significantly correlated with number of primary branches (0.4015), siliqua per plant (0.505), seeds per siliqua (0.79648), siliqua length (0.37037) and seed yield per plot (0.40931), while, it was negatively and non-

significantly associated with number of secondary branches (-0.36663) and protein contents (0.1372) at genotypic level.

Shah et al. (2007) hybridized an Australian canola genotype 'Dunkeld' and a local rapeseed mutant variety 'Abasin-95' that resulted in a new improved variety under the name "DURR-E-NIFA" for general cultivation in the country. DURR-E-NIFA is manifested in the form of increase in seed size, decrease in plant height, stiff stem, broader adaptability as compared to check variety 'Shiralee'. The large seed size of 'DURR-E-NIFA' is the main contributing factor towards the increase in seed yield compared to Shiralee. Short stature and stiff stem of 'DURR-ENIFA' helps in showing resistance to lodging. DURR-E-NIFA has 12.5% high seed yield potential, up to 9.7% higher oil content of canola quality compared to the commercial variety.

Amjad (2007) found *B. napus* susceptible as compared to *B. campestris*. Based on his results during preliminary screening trials he ranked varieties in descending order as Bubul-98 followed by RBN-3057, RBN-3255, RBN-03041, Rain Bow, RBN-03075, Zafar-2000, Gobhi Sarson, RBN-03033, Km- 158, Poorbi Raya, RL-18, Khanpur Raya, KJ-147, RBJ-02-19, RBJ-3031, RBJ-2050, KJ-151, RBJ-3041, RBJ-02-7, Bhuri Sarson, Toria and Peeli Sarson. He concluded that for the propagation of aphid population 2nd week of February provided suitable environment followed by third week of February. Bubul-98 showed maximum host plant susceptibility indices (HPSI) i.e., 20.32% while Khanpur ray a (*B. juncea*) showed minimum HPSI i.e., 14.40%. The impact of temperature and rainfall on the population of *L. erysimi* and *B. brassicae* was negative but non-significant, whereas relative humidity showed positive and non-significant correlation with both the species.

Tahir et al. (2007) in a field experiment on growth and yield of canola in 2005-06 found that plant height was 180.66 cm, branches per plant 20.03, Siliqua per plants 318.54, seed per siliqua 31.12, 1000-seed weight 3.93, seed yield per plant 3.65 grams), seed oil content 44.38 and protein content 20.52. The oil and protein contents of the seed were not affected significantly by varying irrigation levels.

Abbas et al. (2008) assessed parental lines along with five F2s for biochemical parameters using Near Infrared Reflectance Spectroscopy (NIRS). Parental lines contain more oil 45.85% as compared to F2s 42.26% while the F2s contain more protein 25.92% as compared to the parents 23.70%. Both parents and F2 contained high glucosinolate and fatty acids contents.

Ahmad et al. (2008) studied locally developed, improved genotype of *Brassica napus* viz., HS-98, and compared its performance with the established commercial varieties viz., Dunkled, Rainbow, Oscar and Altex. The agronomic traits taken into consideration were siliqua per plant, siliqua length, siliqua width, pedicle length and 1000 seed weight. The biochemical parameters included the percentage of oil in the seed, oleic acid, linolenic acid, protein and seed moisture. The mean squares for siliqua per plant, siliqua length and 1000 seed weight were significant at 1% level of probability, whereas siliqua width and pedicel length were non significant. HS-98 had maximum number of siliqua per plant (156.0) and siliqua length per plant (6.7 cm) and therefore high yielding among all the genotypes. The seed protein was highest (25.1%) in HS-98 followed by Rainbow, Oscar, Altex and Dunkled.

Capinera (2008) observed that Cabbage aphid may reduce plant growth by 35%, the number of side branches by 43%, and the oil content by over 10%. Aphid may cause 85% yield loss and may induce the increase in glucosinolate content in rape seed.

Khan et al. (2008a) evaluated six F3:4 inter-specific brassica populations together with three checks for their genetic variability and correlation among quality traits at Peshawar. Highly significant genetic variation ($P \leq 0.01$) existed among brassica populations for oil content, glucosinolate, oleic acid, linolenic acid and erucic acid contents. Non-significant ($P > 0.05$) variation was recorded for protein content. The maximum oleic acid (53.8%) and minimum linolenic acid (9.4%) were recorded for the population 19-83-5, while minimum glucosinolates (50.1 μm g^{-1}) and erucic acid (32.4%) were recorded in population 15-20-1 and 19-2-2 respectively.

Khan et al. (2008b) evaluated six F3:4 inter-specific brassica populations along with three checks for genetic variability for agronomic characters. Highly significant ($P < 0.05$) genetic variations were recorded for plant height. Maximum number of siliquae main receme^{-1} (94) was observed for population 19-2-2. The population 15-20-1 produced maximum primary branches (15).

Amer et al. (2009) conducted a study to develop insect pest management strategy by exploring host plant resistance in canola, *Brassica napus* L., and seasonal abundance of aphids at Multan, Bahawalpur and Dera Ghazi Khan in Southern Punjab, Pakistan. Two aphid species, *Brevicoryne brassicae* L. and *Lipaphis erysimi* Kalt. were observed as the most devastating pests. Populations of *B. brassicae* were more than that of *L. erysimi*. All the varieties evaluated were found susceptible and weekly population of both the species of aphids did not differ significantly from their appearance till maturity of the crop. Appearance of aphids at all the locations was not uniform. However, highest population was recorded during last week of February to second week of March. The seasonal activity of the aphids is described and it is recommended that application of insecticides is inevitable to avoid economic damage. Development of insect pest management strategy against aphids by exploring sources of plant resistance and seasonal abundance of aphids on *B. napus* is reported from this region for the first time.

Islam et al. (2009) studied twenty-two genotypes of *Brassica (B. rapa, B. juncea,* and *B. napus)* for correlation co-efficient between major fatty acids and path co-efficient analysis to partition the cause and effect relationship into direct and indirect components. Correlation coefficient of major fatty acids revealed that significant and positive correlation was between palmitic and oleic acids, palmitic and linolenic acids, palmitic and cicosenoic acids, oleic and cicosenoic acids, linolenic and linolenic acids and cicosenoic and erucic acids, while significant and negative correlation was observed between palmitic and erucic acids, stearic and linolenic acids and oleic and erucic acids. Path coefficient revealed that direct effect of all fatty acids except palmitic acid on oil content was positive. Indirect effect of erucic acid through all other fatty acids except

palmitic acid on oil content was negative, indirect effect of palmitic acid via all other fatty acids except erucic acid was positive.

Munthali (2009) studied resistance of nine cabbage (*Brassica oleracea* van *capitata*) cultivars, Big cropper, Cape Spitz, Copenhagen Market, Conquistador, Drumhead, Giant Drumhead, Glory of Enkhuizen, Grandslam and Hercules to cabbage aphid (*Brevicoryne brassicae*) in greenhouse experiments conducted at the Botswana College of Agriculture, Gaborone, Botswana. Cabbage aphids caused 85% leaf damage on the most susceptible cultivar, Drumhead, and only 30.9 and 44.6% on the more resistant cultivars, Grandslam and Copenhagen Market, respectively. Drumhead had the lowest number of aphids per leaf, showing the antibiosis mechanism of resistance to *B. brassicae* and yet it suffered the most severe damage. Although Copenhagen Market was resistant to cabbage aphid damage, it had the greatest abundance of aphids per leaf, showing that it used the tolerance resistance mechanism against cabbage aphids. Conquistador, Glory of Enkhuizen, Grandslam and Hercules, which gave the lowest combined effect of number of aphids multiplied by percentage damaged leaves per plant were the best varieties for use by farmers. However, since they only achieved partial resistance to the cabbage aphid, their use is recommended in combination with a low dose of insecticide.

Rahman et al. (2009) evaluated five rapeseed genotypes for agronomic parameters, yield, oil quantity and quality. Significant differences were observed for all the parameters except oil and protein percentage. The genotype Siren outperformed the rest of genotypes in yield potential (1104 kg/ha), followed by MRS-1 (866.67 kg/ha). For yield contributing characters like length of inflorescence and siliquae per plant, genotype Siren again showed good results that are, 51.3 cm and 136.5 siliquae /plant, respectively. The genotype Siren also showed low glucosinolate (44.82 µmol/g), erucic acid (23.67 µmol/g) and higher amounts of oleic acid (59.01%). Due to its high yield and oil quality, the genotype Siren is recommended for general cultivation in the area and further use in breeding programs for *Brassica napus.*

Kumar et al. (2010) investigated the changes in total glucosinolate in leaves, roots and stem at 3 developmental stages, siliqua and seeds of four advanced breeding lines of Indian mustard were during the years 2008–09. Higher glucosinolates levels were found in leaves than in stem and roots except for roots at 45 days after sowing (DAS). Glucosinolates in stem and roots decreased at higher rate in comparison to that of leaves. Leaf glucosinolates at 45 DAS had positive relationship with that of 60 DAS (r = 0.871). Total glucosinolates in seeds were also positively correlated (r = 0.814) and hence could be a good criterion for identifying low glucosinolates lines at early stage.

Rasool (2010) conducted study to determine the impact of various physico-morphological plant characters viz., leaf area (cm), chlorophyll contents (%), number of nodes per tiller, inter-nodal distance (cm), plant height (cm), number of grains per tiller, number of spikelets, spike length (cm), number of hair on midrib (per cm) and lamina (per cm) and length of hair(µm) on midrib and lamina on the population fluctuation of aphids in different genotypes of wheat during 2009. The data were processed for simple correlation and multiple linear regression analysis. The results showed significant differences among genotypes and dates of observation regarding aphids‟ population. Maximum population of aphids (46.07/tiller) was observed on February 24, 2009, which decreased subsequently in the coming dates of observation. Non-significant correlation among population of aphids and all the physico-morphological plant characters under study on wheat crop were observed.

CHAPTER-III

MATERIALS AND METHODS

The research work of "Screening of Genetically Diversified *Brassica* Genotypes against Aphids" was conducted at the Agricultural Research Farm of Khyber Pakhtunkhwa (KP) Agricultural University Peshawar during the cropping seasons of 2006-2008. Twelve *Brassica* genotypes were obtained from the Institute of Biotechnology and Genetic Engineering (IBGE), KP Agricultural University Peshawar and grown in the Agricultural Research Farm (Experiment-I) and Screenhouse (Experiment-II) of the University for screening against aphids.

List of Brassica genotypes studied for screening against aphids during 2006-08.

S.No.	Brassica Species	Genotype
1.	*Brassica napus*	Westar
2.	*B. napus*	Ganyou-5
3.	*B. napus*	Rainbow
4.	*B. napus*	Oscar
5.	*B. napus*	Vangard
6.	*B. napus*	Crusher
7.	*B. napus*	Torch
8.	*B. napus*	Legend
9.	*B. napus*	Altex
10.	*Brassica juncea*	Raya Anmol
11.	*Brassica carinata*	Peela Raya
12.	*Brassica campestris*	T-16-401

3.1 Experiment-I: Field Experiment

3.1.1 Relative Abundance of Aphids Population on Brassica Genotypes

To determine relative abundance of aphid's population on brassica twelve (12) Brassica genotypes were sown in plots measuring 5x4 meters, having rows of 5 meters, with 75 cm row-to-row distance and 40-50cm plant-to-plant distance with four replications using a Randomized Complete Block Design (RCBD). Each genotype was sown in four rows. Standard agronomic practices were applied to the crop throughout the cropping season.

The experiment was carried out for two consecutive growing seasons (2006-07 and 2007-08). During 2006 the crop was sown on October 21 and in 2007 on November 2.

During the months of February and March data on aphid's population was recorded at ten days interval from five randomly selected plants from each row each time of data collection. Number of aphids was recorded from 1st, 2nd and 3rd leaf from the top of each plant and number of aphids/5cm of panicle/shoot (inflorescence).

3.2 Experiment-II: Screenhouse Experiment

3.2.1 Losses due to Cabbage Aphid, *Bravecoryne brassicae* L. in 12 Brassica Genotypes

To determine losses caused due to cabbage aphid, *Bravecoryne brassicae* L. in Brassica genotypes under screenhouse conditions, twelve Brassica genotypes were sown in the screenhouse in plastic pots at the rate of two plants per pot, at the Institute of Biotechnology and Genetic Engineering (IBGE), KP Agricultural University Peshawar on 25-10-2006 and 03-11-2007. At flower-bud initiation stage (coinciding with natural infestation) plants of each genotype in the pot were infested with 0, 5, 10 and 15 aphids/plant.

Aphid's population was recorded when the pest level was at its peek (March 24-28) from stem 5 cm (lower, middle and top-inflorescence), branches 5 cm (lower, middle and apical portion), and leaves (lower, middle and top).

Aphid's population and its effects on yield losses were determined. Yield data was recorded by threshing individual plant. Each treatment was replicated three times and the experiment was laid out in CRBD.

Percent yield losses were calculated from the yield data in infested (treatment) and uninfested (Control) plants by using the following formula.

$$W = \frac{(M-Y) \times 100}{M}$$

Where:

W is the percent yield loss

M is attainable yield in Control

Y is yield in the treatment.

3.2.2 Aphid's Density and yield Components in 12 Brassica Genotypes

The number of aphids on plant and its effect on different yield components Plant height, Primary branches, Siliquae main racem^{-1}, Siliqua length, Seed siliqua^{-1}, 1000-grain weight and Yield plant^{-1}, were recorded at appropriate time.

1. **Aphid Density:** Data on aphid's population was recorded when the pest level was at its peek (March 24-28) from stem 5 cm (lower, middle and top), branches 5 cm (lower, middle and apical portion), and leaves (lower, middle and top).

2. **Yield Plant^{-1}:** Yield per plant was determined by threshing individual plant and weighing its seeds with electronic balance.

3. **Straw Yield:** Straw yield was taken by weighing the whole plant after threshing and removing the seeds.

4. **Plant Height:** When plants reached full blooming stage their height was measured in centimeters from the ground level to the tip of the plant with the help of a 1000 cm measuring rod.

5. **Primary Branches:** Primary branches, which arise from main stem of plant, from base to the top of the plant were counted and recorded.

6. **Siliquae main racem^{-1}:** The number of siliquae were counted on the main raceme and recorded.

7. **Leaves:** Leaves of the plant were counted when aphids infestation was at peak (March 24-28).

3.2.3 Chemical Quality Analysis of Brassica Seeds

Near infrared reflectance (NIR) spectroscopy has been successfully applied as an alternative technique to gas chromatography for the analysis of fatty acid profile in a number of oilseed crops (Reinhardt and Robbelen, 1991). Whole seed samples of all the twelve genotypes were taken to Biochemical Laboratory, Crop Breeding Section of Nuclear Institute for Food and Agriculture (NIFA) Peshawar to scan on Near Infra red (NIR) Spectroscopy System (FOSS 6500 equipped with ISI version 1.02 a software of Infra Soft International) according to the manufacturer's protocol to determine the chemical constituents including oil (%), protein (%), moisture (%), glucosinolates content (µmg-1sample), erucic acid content (% of the total fatty acids), oleic acid content (% of the total fatty acids) and linolenic acid content (% of the total fatty acids).

3.2.4 Statistical Analysis

The data recorded for each parameter was subjected to ANOVA technique by using MSTAT-C, Computer Software and means were subjected to Fisher's Least Significant Difference (LSD) test. Correlation among aphids and yield components were computed with MSTAT-C. Percent losses in yield with various aphids' densities were calculated for each genotype by comparing yields from infested plants with the check.

CHAPTER-IV

RESULTS

4.1 RELATIVE ABUNDANCE OF APHIDS POPULATION ON DIFFERENT BRASSICA GENOTYPES

4.1.1 Aphid's density on 12 Brassica genotypes during 2006-07.

The results in the Table 4.1 reveal that aphids density on 15-02-07 was highest (37.53 aphids/plant) on Legend and lowest (7.67 aphids/plant) on Vangard. On 25-02-07 the highest aphid's density (69.25 aphids/ plant) was also recorded on Legend and the lowest (15.00 aphids/plant) on Vangard. On 08-03-07 aphids density was highest (41.67 aphids/plant) on Legend and lowest (8.17 aphids/plant) on Vangard. On 18-03-07 highest number of aphids (19.56 aphids/ plant) was recorded on Raya Anmol and lowest on Crusher (3.35 aphids/ plant). On 28-03-2007 the highest aphids density was on genotype Rainbow (10.25 aphids/plant) and lowest on Vangard (2.92 aphids/plant). The overall mean density of aphids was highest on Legend (34.56 aphids/plant) and lowest on Vangard (7.57 aphids/plant). During the same period the 10 days average mean temperature ranged from 12.5 -17.4^{o}C, Relative humidity 70.6 – 82.09 and rainfall 0.04 – 16.34 mm (Table 4.2).

Statistical analysis of the data (Table 4.1) showed that non significant differences in aphid population were recorded on Legend, Crusher, Peela Raya and T-16-401 on 15-02-07. On 25-02-07 aphid population was non-significantly different on Legend, Torch and Raya Anmol. On 08-03-07, Legend and Raya Anmol were non-significantly different. On 18-03-07, Raya Anmol, Torch, Legend, Altex and T-16-401 were non-significantly different. On 28-03-07 all genotypes were non-significantly different except Rainbow, Peela Raya and Vangard which were non-significantly different from each other. Over all for the year 2006-07 Legend and Raya Anmol had the highest aphid's density, which were non significantly different from each other. Vangard had the lowest aphid's density which was significantly different than all the other genotypes except Rainbow.

Table 4.1 Mean aphid's density/plant on different Brassica genotypes during 2006-07.

Brassica Genotypes	Mean number of aphids/plant on Brassica Genotypes					Mean aphids density/plant
	15-02-07	25-02-07	08-03-07	18-03-07	28-03-07	
Westar	13.82 def	28.33 c	14.58 ef	5.082 cd	3.42 ab	13.05 ef
Ganyou-5	15.02 cdef	16.63 c	21.92 cde	6.50b cd	3.75 ab	12.76 ef
Rainbow	10.32 ef	19.27 c	13.58 ef	5.88b cd	10.25 a	11.86 fg
Oscar	16.42 cdef	50.58 b	27.17 cd	8.75 bcd	6.64 ab	21.91 bc
Vangard	7.67 f	15.00 c	8.17 f	4.10 d	2.92 b	7.57 g
Crusher	26.25 abcd	19.79 c	17.69 def	3.35 d	3.61 ab	14.14 def
Torch	8.14 ef	57.75 ab	29.83 bc	9.75 abcd	7.875 ab	22.67 b
Legend	37.53 a	69.25 a	41.67 a	15.39 abc	8.98 ab	34.56 a
Altex	12.48 ef	30.58 c	25.00 cd	15.88 ab	3.59 ab	17.51 bcde
Raya Anmol	20.46 bcde	66.67 ab	37.80 ab	19.56 a	4.36 ab	29.77 a
Peela Raya	30.54 ab	26.41 c	18.86 de	5.38 bcd	3.15 b	16.87 cdef
T-16-401	27.22 abc	31.17 c	18.42 de	10.95 abcd	3.80 ab	18.31 bcd

Means within a column followed by similar letters are non-significantly different at 5% level of probability (LSD test).

Table 4.2 Average 10-days Temperature, Relative Humidity and Rain fall during February and March, 2007.

Dates	15.02.07	25.02.07	08.03.07	18.03.07	28.03.07
Avg. Temp.	11.97	11.88	12.5	13.77	17.4
Avg. Humidity	82.09	78.6	78.5	76.9	70.6
Avg. Rain (mm)	16.34	3.62	2.42	3.08	0.04

4.1.2 Aphid's density on 12 Brassica Genotypes during 2007-08.

The results (Table 4.3) reveal that during the year 2007-08 highest aphids density on 5-02-08 was recorded on Ganyou-5 (44.31 aphids/plant) and lowest on Raya Anmol (5.04 aphids/plant). On 15-02-08 highest aphid's density was on Ganyou-5 (105.8) and lowest on T-16-401 (21.78 aphids/ plant). On 25-02-08 highest aphid's density was on genotype T-16-401 (85.73 aphids/plant) and lowest on Legend (14.25 aphids/plant). On 07-03-08 highest aphid's density was recorded on Ganyou-5 (61.00 aphids/plant) and lowest on Vangard (10.83 aphids/plant).On 17-03-08 highest number of aphid's per plant was recorded on Ganyou-5 (50.04 aphids/plant) and lowest on Vangard (3.13 aphids/plant). The overall mean density of aphids for 2007-08 was highest on Ganyou-5 (56.97 aphids/plant) and lowest on Vangard (18.10 aphids/plant). During the same period the 10 days average mean temperature ranged from 15.4 -20.35^{o}C, Relative humidity 52.5 – 77.02 and rainfall 0.0 – 32.07 mm (Table-4.4).

Analysis of the data showed that on 05-02-08 Ganyou-5 had significantly the highest aphid's density. This was followed by Legend which was non-significantly different than Rainbow and Westar in number of aphid's density. Raya Anmol had the lowest aphid's density which was non-significantly different than Altex and T-16-401. On 15-02-08, Ganyou-5 had the highest aphid's density which was non-significantly different than Legend, Oscar and

Rainbow. While T-16-401 had the lowest aphids density that was non-significantly different than Raya Anmol, Peela Raya, Torch, Altex, Vangard and Crusher. On 25-02-08 T-16-401 had significantly the highest aphids density followed by Raya Anmol which was non-significantly different than Altex and Torch. Legend had the lowest aphid's density which was non-significantly different than Westar, Ganyou-5 and Vangard.

On 07-03-08 Ganyou-5 had the highest aphids which were non-significantly different than Legend. Vangard had the lowest aphid's density which was non-significantly different than crusher, Torch, Altex, Raya Anmol, Peela Raya and T-16-401 and Oscar. On 17-03-08 Ganyou-5 had significantly the highest aphid's density followed by Rainbow, Oscar and T-16-401, which were non-significantly different in aphid's density. Vangard had the lowest aphid's density which was non-significantly different than Crusher, Legend, Raya Anmol, Altex and Torch.

Over all for the year 2007-08 Ganyou-5 had significantly highest aphid's density. It was followed by Rainbow, Legend, Oscar and Westar. Lowest aphid's density was recorded in Vangard, which was non-significantly different than Crusher, Raya Anmol and Altex.

Table 4.3 Mean aphid's density/plant on different Brassica genotypes during 2007-08.

Brassica Genotypes	Mean number of aphids/plant on Brassica Genotypes					Mean aphids density/plant
	5-02-08	15-02-08	25-02-08	07-03-08	17-03-08	2007-08
Westar	21.81 bcd	63.42b c	23.88 hi	42.42 bc	17.38 cde	33.78 bcd
Ganyou-5	44.31 a	105.8 a	23.69 hi	61.00 a	50.04 a	56.97 a
Rainbow	22.39 bc	84.21 ab	30.54 fgh	37.83 cd	34.31 b	41.85 b
Oscar	15.32 ef	82.58 ab	39.83 efg	27.50 cde	29.92 bc	39.03 bc
Vangard	11.24 fg	37.17 cd	28.17 ghi	10.83 e	3.13 f	18.10 f
Crusher	10.66 g	35.29 d	51.08 cde	10.88 e	5.58 ef	22.70 ef
Torch	17.86 de	41.79 cd	57.63 bcd	14.17 e	9.13 def	28.11 de
Legend	25.85 b	97.83 a	14.25 i	57.04 ab	11.58 def	41.31 b
Altex	7.66 gh	33.67 d	58.96 bc	16.38 e	11.52 def	25.64 def
Raya Anmol	5.04 h	29.04 d	66.40 b	17.50 e	8.86 def	25.36 def
Peela Raya	21.08 cd	41.96 cd	44.25 def	23.58 de	20.23 cd	30.22 cde
T-16-401	7.53 gh	21.78 d	85.73 a	20.63 de	21.63 bcd	31.46 cde

Means within a column followed by similar letters are non-significantly different at p=0.05(LSD-test).

Table 4.4 Average 10-days Temperature, Relative Humidity and Rain fall during February and March, 2008.

Dates	05.02.08	15.02.08	25.02.08	07.03.08	17.03.08
Avg. Temp.	20.35	18	19.9	15.60	15.4
Avg. Humidity	52.5	77.2	70.8	70.30	76.3
Avg. Rain (mm)	0	32.07	0.81	2.05	4.8

4.1.3 Mean aphids density on 12 Brassica Genotypes during 2006-07 and 2007-08

The results (Table 4.5) show that mean aphids density during 2008 was higher than 2007. In comparison the average temperature was higher and relative humidity was lower during 2008 than 2007, showing some effect of weather on aphid's density.

The results (Table 4.5) show that on the basis of two years mean data on 12 Brassica genotypes the lowest aphids density per plant was found on Vangard (12.84 aphids/plant), which was significantly different than all the other genotypes. The highest aphids density per plant was recorded for Legend (37.94 aphids/plant) which was not significantly different than Gainyou-5 (34.87 aphids/plant) but significantly different than all the other genotypes.

Vangard exhibited high degree of antixenosis/resistance to aphids (12.84 aphids/plant) which was followed by Crusher (18.42), Altex (21.57), Westar (23.41) and Peela Raya (23.55) while, T-16-401 (24.89), Torch (25.39), Rainbow (26.86), Raya Anmol (27.57) and Oscar (30.47aphids/plant) exhibited moderate degree of antixenosis/ resistance against aphids.

Table 4.5. Mean aphid's density/plant on different Brassica genotypes during 2006-07 and 2007-08.

Brassica Type	Name of Genotypes	Year		Mean
		2007	2008	
B. napus	Westar	13.05 ef	33.78 bcd	23.41 def
B. napus	Ganyou-5	12.76 ef	56.97 a	34.87 ab
B. napus	Rainbow	11.86 fg	41.85 b	26.86 cde
B. napus	Oscar	21.91 bc	39.03 bc	30.47 bc
B. napus	Vangard	7.57 g	18.10 f	12.84 g
B. napus	Crusher	14.14 def	22.70 ef	18.42 f
B. napus	Torch	22.67 b	28.11 de	25.39 cde
B. napus	Legend	34.56 a	41.31 b	37.94 a
B. napus	Altex	17.51 bcde	25.64 def	21.57 ef
B. juncea	Raya Anmol	29.77 a	25.36 def	27.57 cd
B. carinata	Peela Raya	16.87 cdef	30.22 cde	23.55 def
B. campestris	T-16-401	18.31 bcd	31.46 cde	24.89 de

Means within a column followed by similar letters are non-significantly different at p=0.05(LSD-test).

4.1.4 APHIDS DENSITY AND YIELD COMPONENTS OF 12 BRASSICA GENOTYPES UNDER FIELD CONDITIONS

4.1.4.1 Plant Height

The different characteristics of different Brassica genotypes tested for their relative resistance/tolerance against aphids attack are listed in the Table 4.6. The data reveals that highest plant height was recorded in genotype Peela Raya (214.3 cm), followed by Altex, T-16-401, Ganyou-5, Oscar, Crusher, Raya Anmol, Rainbow, Legend, Torch, Vangard and lowest in Westar with plant height 195.1, 192.3, 176.4, 173.4, 177.1, 173.6, 165.8, 165.5, 160.6, 162.2 and 150.4 cm, respectively.

Statistical analysis of the data of plant height (Table 4.6) showed that plant height was significantly longest in Peela Raya. This was followed by Altex which was non-significantly different than T-16-401. Ganyou-5, Oscar, Crusher and Raya Anmol were non-significantly different from each other. Similarly plant height among Rainbow, Legend, Torch and Vangard was non-significantly different. Westar was significantly shortest of all the genotypes.

The result of the analysis of aphid's population and yield components of the 12 Brassica genotypes (Table 4.6) showed that maximum plant height was recorded in Peela Raya (214.3cm) with an average aphid's density of 23.55 per plant and minimum plant height in Westar (150.4 cm) with aphid's density of 23.41 aphids per plant.

4.1.4.2 Primary Branches

Number of primary branches was highest for Peela Raya (19.20) followed by Raya Anmol, T-16-401, Torch, Altex, Ganyou-5, Legend, Crusher, Oscar, Vangard, Rainbow and lowest in Westar with the primary branches 10.41, 10.01, 9.84, 9.39, 8.89, 8.45, 8.28, 8.25, 8.08, 8.08 and 6.94, respectively.

Analysis of the data (Table 4.6) showed that the numbers of primary branches were significantly the highest in Peela Raya with 19.20 branches among the 12 genotypes. There was no significant difference in the number of

primary branches in Raya Anmol, T-16-401, Torch and Altex. The numbers of primary branches were non-significantly different among crusher, Oscar, Vangard, Legend and Rainbow which ranked in 3rd position. Westar had significantly the lowest number of primary branches (6.94).

The number of primary branches was highest for Peela Raya with 19.20 and lowest for Westar with 6.94 branches. The lowest aphid density of 12.84 was recorded on Vangard and the highest 37.94 aphids/plant was recorded on Legend. The correlation of aphids with primary branches was non significant negative (-0.05).

4.1.4.3 Siliquae main raceme^{-1}

Number of siliquae main raceme^{-1} was highest for genotype Vangard (70.20), followed by Torch, Ganyou-5, Rainbow, Crusher, Legend, Westar, Oscar, Raya Anmol, T-16-401, Altex and lowest in Peela Raya with number of siliqua 63.11, 61.46, 58.28, 55.36, 53.80, 50.88, 48.85, 43.63, 38.49, 35.04 and 20.76, respectively.

The analysis of the data of the siliquae main racem^{-1}of the 12 Brassica genotypes (Table 4.6) showed that significantly the highest number of siliqua on main raceme were recorded on Vangard (70.20 siliqua). The number of siliquae on main raceme in Torch (63.11) and Ganyou-5 (61.46) were not different significantly. Similarly there was no significant difference in the number of siliquae recorded on Crusher (55.36), Legend (53.80) and Westar (50.88). Peela Raya with 20.76 siliquae on main raceme was significantly the lowest than all genotypes.

Number of siliquae main raceme^{-1} was highest for genotype Vangard (70.20) and lowest in Peela Raya (20.76 siliqua) with corresponding aphids density of 12.84 and 23.55, respectively. This shows that the aphid density affect the number of siliquae main raceme^{-1}.

4.1.4.4 Siliqua Length (cm)

Siliqua length size was longest in the genotype Ganyou-5 (8.31) followed by Westar, Vangard, Torch, Oscar, Legend, Rainbow, Crusher, Peela

Raya, T-16-401, Raya Anmol and shortest in Altex with 8.23, 7.60, 6.94, 6.92, 6.91, 6.76, 6.12, 5.10, 4.69, 4.41 and 4.02, respectively.

Statistical analysis of the results of siliqua length of the 12 Brassica genotypes (Table 4.6) showed that siliqua length was significantly the longest (8.31) for genotype Ganyou-5 and Westar with siliqua length 8.23, closely followed, but significantly different was Vangard (7.6). Siliqua length in Torch (6.94), Oscar (6.92), Legend (6.91) and Rainbow (6.76) was non-significantly different in the order. Altex had the shortest siliqua length (4.02) which was significantly different from the rest of the genotypes.

Siliqua length was the longest (8.31cm) for genotype Ganyou-5 and the shortest (4.02) for Altex with aphid's density of 34.87 and 21.57, respectively. This shows that the once siliqua grow on a genotype, the aphid density does not affect the length of siliqua.

4.1.4.5 Seed per Siliqua

Seed per siliqua was highest in the genotype Oscar (23.57 seeds) followed by Ganyou-5, Rainbow, Westar, Vangard, Crusher, Torch, Peela Raya, Altex, T-16-401 and lowest in Legend with 17.54, 17.11, 16.35, 15.89, 15.57, 13.55, 11.58, 10.04, 9.99, 9.74 and 9.38 seeds, respectively.

The statistical analysis of the results of seed siliqua^{-1} of the 12 Brassica genotypes (Table 4.6) showed that Oscar had significantly the highest number of seeds per siliqua (23.57 seeds). This was followed by Ganyou-5 (17.54 seeds) and Rainbow (17.11 seeds), the difference between which was non significant. The difference between the number of seeds siliqua^{-1} in Legend (9.38 seeds) was non-significantly different among Raya Anmol (10.04 seeds), Altex (9.99 seeds) and T-16-401 (9.74).

The number of seed siliqua^{-1} was the highest (23.57) in Oscar and lowest in Legend (9.38) with aphid's densities of 30.47 and 37.94, respectively. This result shows that aphid density doesn't affect the number or seeds siliqua^{-1}.

4.1.4.6 1000 Seed Weight (grams)

1000 seed weight was highest in the genotype Westar (4.80) followed by Oscar, Rainbow, Ganyou-5, Torch, Legend, Vangard, Crusher, Raya Anmol, Peela Raya, Altex and lowest in T-16-401 with 4.65, 4.57, 4.56, 4.39, 4.11, 4.02, 3.98, 3.83, 3.71, 3.67 and 3.37, respectively.

Analysis of the result of 1000-seed weight of the 12 Brassica genotypes (table 4.6) showed that significantly highest 1000-seeds weight was found in Westar (4.80 grams) which was statistically similar to Oscar (4.65), Rainbow (4.570), Ganyou-5 (4.56) and Torch (4.39 grams). The lowest 1000-seeds weight was recorded in T-16-401 (3.37) which did not differ significantly to Raya Anmol (3.83), Peela Raya (3.71) and Altex (3.67).

1000 seeds weight was highest in Westar (4.80) and lowest in T-16-401 (3.37) with aphid's densities of 23.41 and 24.89 aphids/ plant, respectively. The results show that aphid population does not affect the seed weight directly.

4.1.4.7 Seed Yield Grams Plant^{-1}

Seed yield per plant was highest in the genotype Peela Raya (45.89), followed by Raya Anmol, Crusher, Legend, Vangard, Torch, Rainbow, Altex, Gainyou-5, T-16-401, Oscar and lowest in Westar with 36.83, 31.35, 30.67, 29.16, 29.04, 26.91, 26.84, 24.77, 24.61, 22.03 and 20.75 seeds, respectively. In the *B. napus* group highest seed yield plant^{-1} was recorded in genotype Crusher (31.35 g/plant).

Seed yield plant^{-1} (Table 4.6) was significantly highest for Peela Raya (45.89g/plant). This was followed by significantly different seed yield plant^{-1} recorded in Raya Anmol (36.83). Raya Anmol was non-significantly different from Crusher, Legend, Vangard, and Torch. Westar and Oscar had the lowest seed yield plant^{-1}. This was non-significantly different from all other genotypes of *B. napus* group.

4.1.4.8 Seed Yield (kg ha^{-1})

Seed yield kg ha^{-1} was highest (2386 kg/ha) in Peela Raya, followed by Raya Anmol, Crusher, Legend, Vangard, Torch, Rainbow, Altex, Gainyou-5, T-

16-401, Oscar and lowest in Westar with 1915, 1630, 1595, 1516, 1510, 1399, 1396, 1288, 1280, 1146 and 1079, respectively. In *B. napus* group highest seed yield kg ha^{-1} was recorded in genotype Crusher (1630 kg ha^{-1}).

Analysis of the data showed (Table 4.6) that Peela Raya had the maximum seed yield followed by Raya Anmol, Crusher, Legend, Vangard and Torch, the difference among which was non significantly different. Westar had the lowest seed yield, however, it proved to be non-significantly different than Rainbow, Altex, Ganyou-5, T-16-401, Oscar, Vangard and Torch.

4.1.4.9 Biological Yield (kg ha^{-1})

Biological yield was highest in Peela Raya (16270 kgha^{-1}), followed by Raya Anmol, Altex, Vangard, Torch, T-16-401, Legend, Oscar, Crusher, Westar, Rainbow and lowest in Ganyou-5 with 15810, 14430, 14360, 13860,13460, 13410, 13260, 12780, 12780, 12540, 12380 and 12150 kg/ha, respectively. In *B. napus* group highest Biological yield kg ha^{-1} was recorded in genotype Altex (14430 kg ha^{-1}).

Statistical analysis of Biological yield (kg ha^{-1}) (Table 4.6) showed that calculated biological yield was the highest and non-significantly different in Peela Raya and Raya Anmol. On the second position were Altex, Vangard, Torch, T-16-401, Legend and Oscar, which proved to be non-significantly different in biological yield ha^{-1}. Ganyou-5 had the lowest biological yield, but non-significantly different than biological yield of Westar, Rainbow and Crusher.

Table 4.6. Aphids density and Yield components of 12 genetically diversified Brassica genotypes during 2006-08.

Genotypes	Aphids Density /Plant	Plant Height (cm)	Primary Branches (No)	Siliquae Raceme^{-1} (No)	Siliqua Length (cm)	Seeds Siliqua^{-1} (No)	1000 g Weight (g)	Seed Yield g /Plant	Seed Yield (Kg/ha^{-1})	Biological Yield (kgha^{-1})
Westar	23.41 def	150.4e	6.94f	50.88ef	8.23a	16.35c	4.80a	20.75 d	1079d	12540de
Ganyou-5	34.87 ab	176.4c	8.89cde	61.46bc	8.31a	17.54b	4.56ab	24.77cd	1288cd	12150e
Rainbow	26.86 cde	165.8d	8.08e	58.28cd	6.76c	17.11b	4.57ab	26.91cd	1399cd	12380de
Oscar	30.47 bc	173.4c	8.25e	48.85f	6.92c	23.57a	4.65a	22.03d	1146d	13260bcde
Vangard	12.84 g	162.2d	8.08e	70.20a	7.60b	15.89cd	4.02cd	29.16bcd	1516bcd	14360b
Crusher	18.42 f	177.1c	8.28e	55.36de	6.12d	15.57d	3.98cd	31.35bc	1630bc	12780cde
Torch	25.39 cde	160.6d	9.84bc	63.11b	6.94c	13.55e	4.39abc	29.04bcd	1510bcd	13860bc
Legend	37.94 a	165.5d	8.45de	53.80de	6.91c	9.38g	4.11bcd	30.67bc	1595bc	13410bcd
Altex	21.57 ef	195.1b	9.39bcd	35.04h	4.02g	9.99g	3.67de	26.84cd	1396cd	14430b
Raya Anmol	27.57 cd	173.6c	10.41b	43.63g	4.41f	10.04g	3.83de	36.83b	1915b	15810a
Peela Raya	23.55 def	214.3a	19.20a	20.76i	5.10e	11.58f	3.71de	45.89a	2386a	16270a
T-16-401	24.89 de	192.3b	10.01 b	38.49h	4.69f	9.74g	3.37e	24.61cd	1280cd	13460bcd

Means in columns followed by similar letters are non-significant at = 0.05% level of probability (DMR test)

4.1.5 APHIDS DENSITY AND BIOCHEMICAL CONTENTS OF BRASSICA GENOTYPES UNDER FIELD CONDITIONS

Aphid's density and biochemical contents of different Brassica genotypes under field conditions are presented in Table 4.7.

4.1.5.1 Aphids Density

The analysis of the results of biochemical contents of the 12 Brassica genotypes revealed that aphids density was highest on the genotype Legend (37.94 aphids/plant), followed by Ganyou-5 (34.87), Oscar (30.47), Raya Anmol (27.57), Rainbow (26.86), Torch (25.39), T-16-401 (24.89), Peela Raya (23.55), Westar (23.41), Altex (21.57), Crusher (18.42) and lowest in Vangard (12.84).

4.1.5.2 Biochemical Contents

4.1.5.2.1 Oil Contents (%)

The analysis of the results of biochemical contents of the 12 Brassica genotypes are shown in Table 4.7. Oil contents of different genotypes were highest in Oscar (52.10), followed by Vangard (51.51), Legend (50.81), Altex (50.50), Rainbow (50.46), Torch (50.43), Peela Raya (50.38), Crusher (50.33), Ganyou-5 (49.98), Raya Anmol (47.65), Westar (47.36) and lowest in T-16-401 (42.73).

4.1.5.2.2 Protein (%)

Protein contents (Table 4.7) was highest (25.12) in genotype T-16-401, followed by Westar (23.94), Raya Anmol (23.16), Torch (22.64), Legend (22.46), Ganyoy-5 (22.20), Altex (22.18), Peela Raya (21.80), Crusher (21.63), Rainbow (21.19), Oscar(20.71) and lowest in Vangard (20.38).

Highest aphid's density (37.94 aphids/ plant) was found in Legend which has (22.46%) protein contents and lowest aphid's density (12.84 aphids/ plant) was found in Vangard that has (20.38%) protein.

4.1.5.2.3 Glucosinolates (μ mg^{-1}) Content

The glucosinolates content of the 12 Brassica genotypes (Table 4.7) showed that glucosinolate contents were highest (132.7) in T-16-401, which was followed by Raya Anmol (115.5), Peela Raya (109.4), Westar (88.49), Torch (88.38), Ganyou-5 (88.0), Legend (82.53), Crusher (81.76), Oscar (80.68), Vangard (80.05), Altex (79.37) and lowest in Rainbow (67.35). The glucosinolates content of the genotypes ranged from 67.35 to 132.7 with a mean value of 100.02.

The highest and the lowest glucosinolates μ mg^{-1} (132.7) and (67.35) were found in T-16-401 and Rainbow with corresponding average aphids density of 24.89 and 26.86 aphids per plant, respectively.

4.1.5.2.4 Moisture (%)

The moisture content (Table 4.7) in the genotype Oscar (7.09) was highest which was followed by Vangard (7.05), Legend (7.0), Torch (6.93), Westar (6.86), Rainbow (6.84), Crusher (6.75), Altex (7.0), Ganyou-5 (6.44), Raya Anmol (5.28), T-16-401 (5.08) and lowest in Peela Raya (4.51). The moisture contents of the Genotype ranged from 4.51 to 7.09 with a mean value of 5.8%. Peela Raya, T-16-401 and Raya Anmol with moisture values 4.51, 5.08 and 5.28, respectively, were significantly different than the rest of the genotypes which were all similar.

The highest and the lowest moisture contents (7.09) and (4.51) were found in Oscar and Peela Raya with corresponding average aphid's density of 30.47 and 23.55 aphids per plant, respectively.

4.1.5.2.5 Oleic Acid (%)

The oleic acid content found in the 12 Brassica genotypes (Table 4.7) was highest (54.74) in Westar, which was followed by Rainbow (52.48), Crusher (51.48), Legend (49.15), Vangard (48.03), Ganyou-5 (47.81), Oscar (47.73), Torch (45.59), Altex (44.63), T-16-401(32.48), Raya Anmol (30.9) and lowest in Peela Raya: (29.93). The oleic acid content ranged from 29.93 to 54.74 with a mean value of

42.33. There were significant differences among the Brassica genotypes for oleic acid contents.

The highest and the lowest oleic acid (54.74) and (29.93) were found in Westar and Peela Raya with corresponding average aphids density of 23.41 and 23.55 aphids per plant, respectively.

4.1.5.2.6 Linolenic Acid (%)

The linolenic acid contents as given in Table 4.7 were highest (12.86) in Raya Anmol, followed by Peela Raya (11.79), T-16-401 (10.78), Oscar (9.43), Crusher (9.37), Torch (9.35), Vangard (9.24), Altex (9.23), Legend (9.06), Ganyou-5 (8.78), Rainbow (8.75) and lowest in Westar (7.65). The linolenic acid content of the genotypes ranged from 7.65 to 12.86 with a mean value of 10.26. The linolenic acid content found in different Brassica genotypes was significantly different.

The highest and the lowest linolenic acid (12.86) and (8.75) were found in Raya Anmol and Rainbow with corresponding average aphids density of 27.57 and 26.86 aphids per plant, respectively.

4.1.5.2.7 Erucic Acid (%)

Erucic acid content of the Brassica genotypes as given in Table 4.7 were highest (56.2), in Raya Anmol, which was followed by T-16-401 (52.23), Peela Raya (49.48), Altex (47.32), Torch (45.99), Oscar (45.19), Vangard (44.25), Ganyou-5 (43.5) Legend (40.41), Westar (37.68), Rainbow (36.53) and lowest in Crusher (36.44). The erucic acid content of the genotypes ranged from 32.1 to 59.4 with a mean value of 45.75.

The highest and the lowest erucic acid (56.20) and (36.53) were found in Raya Anmol and Rainbow with corresponding average aphids density of 27.57 and 26.86 aphids per plant, respectively.

Table 4.7 Quality characteristics of 12 genetically diversified genotypes during 2006-08.

Genotypes	Aphids density/Plant	Oil (%)	Protein (%)	GSL μ mg^{-1}	Moisture (%)	Oleic Acid (%)	Linolenic Acid (%)	Erucic Acid (%)
Westar	23.41 def	47.36 ab	23.94 ab	88.49 cd	6.86 a	54.74 a	7.65 d	37.68 ef
Ganyou-5	34.87 ab	49.98 a	22.20 ab	88.00 cd	6.44 a	47.81 cde	8.78 cd	43.50 cde
Rainbow	26.86 cde	50.46 a	21.19 b	67.35 d	6.84 a	52.48 ab	8.75 cd	36.53 f
Oscar	30.47 bc	52.10 a	20.71b	80.68 d	7.09 a	47.73 cde	9.43 c	45.19 cd
Vangard	12.84 g	51.51 a	20.38 b	80.05 d	7.05 a	48.03 cde	9.24 c	44.25 cde
Crusher	18.42 f	50.33 a	21.63 ab	81.76 d	6.75 a	51.48 abc	9.37 c	36.44 f
Torch	25.39 cde	50.43 a	22.64 ab	88.38 cd	6.93 a	45.59 de	9.35 c	45.99 bcd
Legend	37.94 a	50.81 a	22.46 ab	82.53 d	7.00 a	49.15 bcd	9.06 c	40.41 def
Altex	21.57 ef	50.50 a	22.18 ab	79.37 d	7.00 a	44.63 e	9.23 c	47.32 bc
Raya Anmol	27.57 cd	47.65 a	23.16 ab	115.5 ab	5.28 b	30.90 f	12.86 a	56.20 a
Peela Raya	23.55 def	50.38 a	21.80 ab	109.4 bc	4.51 b	29.93 f	11.79 ab	49.48 abc
T-16-401	24.89 de	42.73 b	25.12 a	132.7 a	5.08 b	32.48 f	10.78 b	52.23 ab

Means within a column followed by similar letters are non-significant from each other using LSD test at 5% level of probability.

4.2 LOSSES DUE TO *BRAVECORYNE BRASSICAE* IN DIFFERENT BRASSICA GENOTYPES UNDER SCREENHOUSE CONDITIONS

4.2.1 Aphids Density and Yield Losses (%) in Seed Yield of 12 Brassica Genotypes infested with 5-Aphids per Plant at Flower-bud initiation Stage

The results in Table 4.8 revealed that amongst all the Brassica genotypes infested with 5-aphids per plant at flower-flower-bud initiation stage seed yield losses (%) were highest for Torch (44.50%) with aphid's density/plant (59.33). Lowest yield losses (11.08%) were recorded in genotype T-16-401 with 37.33 aphids /plant. Among the *B. napus* group Legend had the lowest yield losses of 16.25% with aphid's density of 69.67 per plant.

Table 4.8 Yield Losses of Brassica Genotypes under Screenhouse Conditions with 5-aphids per plant infestation at Flower-bud initiation Stage during 2006-08.

Brassica Genotypes	Genotypes	Aphids Density /Plant	Actual Yield (Control)	Grams Yield/plant (Infested)	% Yield Losses
Brassica napus	Westar	70.00 bc	5.973 b	4.830 a	19.19 cde
	Ganyou-5	37.83 ef	6.090 b	4.980 a	17.92 de
	Rainbow	106.2 a	5.407 bc	4.053 bc	25.01 bcde
	Oscar	49.33 de	3.620 f	2.553 e	29.38 abcd
	Vangard	74.33 b	4.930 cd	3.207de	34.58 ab
	Crusher	68.50 bc	5.703 bc	3.217 de	43.83 a
	Torch	59.33 cd	6.013 b	3.310 cde	44.50 a
	Legend	69.67 bc	4.807 cde	4.023 bc	16.25 de
	Altex	73.83 b	5.543 bc	4.553 ab	16.99 de
Brassica juncea	Raya Anmol	27.67 f	7.327 a	4.823 a	33.80 abc
Brassica carinata	Peela Raya	30.17 f	4.457 def	2.760 de	37.50 ab
Brassica campestris	T-16-401	37.33 ef	3.973 ef	3.500 cd	11.08 e

Means within a column followed by similar letters are non-significant from each other using LSD test at 5% level of probability.

Statistically there was significant difference amongst the yield losses of tested genotypes from different aphid's densities. However, there was no significant difference among the yield losses in Torch (44.50% losses with aphids density/plant 59.33), Crusher (43.83% losses with aphids density/plant of 68.50), Vangard (34.58% with aphids densities of 74.33), Peela Raya (37.50% yield loss with aphids density/plant of 30.17) and Raya Anmol (33.80% yield losses from aphids density of 27.67). Similarly,

the differences in the percent yield losses among Legend, Altex, Rainbow, Gainyou-5 and Westar were found non-significant.

4.2.2 Aphids Density and Yield Losses (%) in Seed Yield in 12 Brassica Genotypes infested with 10-Aphids per Plant at Flower-bud initiation Stage

The results in Table 4.9 showed that amongst all the Brassica genotypes infested with 10-aphids per plant at flower-flower-bud initiation stage highest yield losses (62.15%) were recorded in genotype Vangard with aphid density/plant of 97.00. Lowest yield losses (22.09%) were recorded in T-16-401 with aphid's density/plant of 54.50. Among the *Brassica napus* group, Legend had the lowest yield losses of 23.65% with aphid's density/plant of 125.7 aphids/plant.

Statistical analysis of the data showed that among all the Brassica genotypes tested the highest seed yield losses (62.15%) in Vangard were non-significantly different from Oscar with 55.38%, Torch (50.34%), Crusher (49.85%) seed yield losses. The lowest yield losses (22.09%) in genotype T-16-401 was non-significantly different from yield losses (23.65%) in Legend from among *B. napus* group.

Table 4.9 Yield Losses of Brassica Genotypes under Screenhouse Conditions with 10-aphids per plant infestation at Flower-bud initiation Stage during 2006-08.

Brassica Genotypes	Genotypes	Aphids Density /Plant	Actual Yield (Control)	Grams Yield/plant (Infested)	% Yield Losses
Brassica napus	Westar	117.0 a	5.973 b	3.923 ab	34.05 cdef
	Ganyou-5	62.67 cd	6.090 b	4.570 a	24.66 ef
	Rainbow	110.0 ab	5.407 bc	3.787 abc	29.48 def
	Oscar	108.0 ab	3.620 f	1.600 f	55.38 ab
	Vangard	97.00 abc	4.930 cd	1.833f	62.15 a
	Crusher	95.83 abc	5.703 bc	2.867 de	49.85 abc
	Torch	77.67 bcd	6.013 b	2.950 de	50.34 abc
	Legend	125.7 a	4.807 cde	3.670 bcd	23.65 f
	Altex	97.00 abc	5.543 bc	3.180 bcd	41.90 bcde
Brassica juncea	Raya Anmol	57.67 d	7.327 a	3.810 abc	48.15 abc
Brassica carinata	Peela Raya	63.50 cd	4.457 def	2.410 ef	45.67 abcd
Brassica campestris	T-16-401	54.50 d	3.973 ef	3.060 cde	22.09 f

Means within a column followed by similar letters are non-significant from each other using LSD test at 5% level of probability.

4.2.3 Aphids Density and Yield Losses (%) in Seed Yield of 12 Brassica Genotypes infested with 15-Aphids per Plant at Flower-bud initiation Stage

The results in Table 4.10 shows that among all the Brassica genotypes infested with 15-aphids per plant at flower-bud initiation stage the highest yield losses of 75.88% occurred in Vangard from 132.7 aphids /plant. The lowest yield losses (29.14%) was recorded in the genotype T-16-401 from 85.17 aphids/plant. Among the *Brassica napus* group the lowest yield losses (43.97%) were recorded in Rainbow from 200.7 aphids/plant.

Statistical analysis of the data showed that there was no significant difference among losses in Peela Raya (68.38%), Oscar (66.04%) and Vangard (75.88%). These were the highest yield losses in the tested genotypes. The losses in Rainbow, Westar and Ganyou-5 were non-significantly different.

Table 4.10. Yield Losses of Brassica Genotypes under Screenhouse Conditions with 15-aphids per plant infestation at Flower-bud initiation Stage during 2006-08.

Yield Losses in Genetically modified Brassica Germplasm					
Brassica Genotypes	Genotypes	Aphids Density /Plant	Actual Yield (Control)	Grams Yield/plant (Infested)	% Yield Losses
Brassica napus	Westar	137.7 cd	5.973 b	3.287 ab	44.67 de
	Ganyou-5	82.83 f	6.090 b	3.453 a	43.35 e
	Rainbow	200.7 a	5.407 bc	3.003 abc	43.97 e
	Oscar	184.3 ab	3.620 f	1.220 f	66.04 abc
	Vangard	132.7 cde	4.930 cd	1.193 f	75.88 a
	Crusher	142.0 c	5.703 bc	2.287 de	59.80 bc
	Torch	101.2 def	6.013 b	2.737 cd	54.08 cde
	Legend	149.2 bc	4.807 cde	2.080 e	56.37 bcde
	Altex	101.5 def	5.543 bc	2.283 de	57.92 bcd
Brassica juncea	Raya Anmol	100.7 ef	7.327 a	2.767 bcd	62.27 bc
Brassica carinata	Peela Raya	103.5 def	4.457 def	1.397 f	68.38 ab
Brassica campestris	T-16-401	85.17 f	3.973 ef	2.773 bcd	29.14 f

Means within a column followed by similar letters are non-significant from each other using LSD test at 5% level of probability.

4.3 APHIDS DENSITY, YIELD AND YIELD COMPONENTS OF 12 BRASSICA GENOTYPES UNDER SCREENHOUSE CONDITIONS

4.3.1 Aphid Density

The data in Table 4.11 revealed that amongst all the Brassica genotypes grown under screenhouse conditions and infested with 0, 5, 10 and 15 aphids/plant at flower-bud initiation stage, highest average aphids density was observed in the genotype Rainbow (138.9), followed by Legend (114.8), Oscar (113.9), Westar (108.2), Crusher (102.1), Vangard (101.3), Altex (90.78), Torch (79.39), Peela Raya (65.72), Raya Anmol (62.0), Ganyou-5 (61.11) and lowest in T-16-401 (59.0) aphids per plant. Among the *B. napus* group Ganyou-5 had the lowest aphid's density per plant.

Rainbow with highest aphid's density was non-significantly different than Legend and Oscar and significantly different than all the other genotypes. The differences among Torch, Peela Raya, Raya Anmol, Ganyou-5 and T-16-401 were non-significant and were significantly different from Oscar, Westar, Crusher, Vangard and Altex, which were non-significantly different from each other.

4.3.2 Seed Yield

In all the 12 Brassica genotypes (Table-4.11), highest seed yield in the control was in the genotype Raya Anmol (7.33), Ganyou-5 (6.09), Torch (6.01), Westar (5.97), Crusher (5.70), Altex (5.54), Rainbow (5.41), Vangard (4.93), Legend (4.89), Peela Raya (4.46), T-16-401 (3.93) and lowest in Oscar (3.62).

In all the 12 Brassica genotypes (Table-4.11), highest average seed yield loss/plant with 61.11 aphids per plant was recorded in Ganyou-5 (4.33 grams/plant), followed by Raya Anmol (4.04), Westar (3.86), Rainbow (3.61), Legend (3.28), T-16-401 (3.02), Torch (3.00), Altex (2.81), Crusher (2.79), Peela Raya (2.23), Vangard (2.08) and the lowest in Oscar (1.79).

Results (Table-4.12) show that the highest average percent seed loss was recorded in Vangard (57.88), followed by Crusher (51.05), Oscar (50.55), Torch

(50.14), Peela Raya (50.07), Altex (49.30), Raya Anmol (44.79), Westar (35.32), Rainbow (33.27), Legend (32.92), Ganyou-5 (28.85) and lowest in T-16-401 (23.24%).

Statistically highest percent seed yield loss was recorded in Vangard which was non-significantly different than Crusher, Oscar, Torch, Peela Raya, Altex and Raya Anmol. All these were significantly different than Ganyou-5 and T-16-401, with lowest yield losses. T-16-401 was non-significantly different than Ganyou-5, Legend, Rainbow and Westar. Correlation among aphids and seed yield percent loss was significant (0.52) (Table-4.13).

3.3.3 Straw Yield

In all the 12 Brassica genotypes (Table-4.11), the average highest straw yield/plant in control was recorded Vangard (30.52), followed by Altex (27.96), Crusher (25.12), Torch (24.95), Raya Anmol (24.41), Westar (24.16), Peela Raya (23.41), Legend (23.34), Ganyou-5 (22.83), T-16-401 (22.42), Rainbow (21.00) and lowest in Oscar (20.46) grams.

In all the 12 Brassica genotypes (Table-4.11), average highest straw yield/plant was recorded in the genotype Vangard (19.61), followed by Westar (18.63), Ganyou-5 (18.18), T-16-401 (17.71), Crusher (17.26), Rainbow 16.57, Torch (15.45), Altex (15.43), Legend (15.41), Oscar (15.16), Raya Anmol (14.70) and lowest in Peela Raya (12.56).

Results (Table-4.12) showed that the highest average percent straw loss was recorded in Peela Raya (46.36) followed by Altex (44.80), Raya Anmol (39.78), Torch (38.08), Vangard (35.73), Legend (33.98), Crusher (31.30), Oscar (25.91), Westar (22.90), Rainbow (21.08), T-16-401 (21.02) and lowest in Ganyou-5 (20.35). Correlation among aphids and Straw yield percent loss was non-significant (0.41) (Table-4.13).

Highest percent loss in Straw was found in Peela Raya, which was non-significantly different than Altex, Raya Anmol, Torch and Vangard. Ganyou-5, with

lowest percent straw loss was non-significantly different than T-16-401., Rainbow, Westar, Oscar and Crusher.

4.3.4 Plant Height (cm)

In the control treatment of all Brassica genotypes (Table-4.11), the highest Plant Height was recorded in the genotype Peela Raya (205.4), followed by Altex (190.8), T-16-401 (178.5), Crusher (161.4), Raya Anmol (160.6), Ganyou-5 (157.4), Legend (157.2) Rainbow (149.5), Oscar (144.1) Torch (143.4), Vangard (140.3) and lowest Westar (134.1).

In all the 12 Brassica genotypes (Table-4.11) average highest plant height was recorded in the genotype Peela Raya (153.4), followed by Altex (138.8), T-16-401 (126.5), Crusher (109.4) Raya Anmol (108.6), Ganyou-5 (105.4), Legend (105.2), Rainbow (97.47), Oscar (92.07), Torch (91.37), Vangard (88.30) and lowest in Westar (82.10).

Results (Table 4.12) show that the average highest percent plant height loss was recorded in the genotype Westar (38.78), followed by Vangard (37.06), Torch (36.27), Oscar (36.09), Rainbow (34.79), Legend (33.07), Ganyou-5 (33.03), Raya Anmol (32.38), Crusher (32.22), T-16-401 (29.13), Altex (27.25) and Peela Raya (25.32) percent. Correlation among aphids and Plant Height percent loss was highly significant (0.75) (Table-4.13).

Westar with highest Plant Height loss was non-significantly different than all the genotypes except T-16-401, Altex, Peela Raya, from which it was significantly different.

4.3.5 Branches Plant^{-1}

In the control treatment of all the 12 Brassica genotypes (Table-4.11), the highest number of Branches plant^{-1} was recorded in Peela Raya (13.50), followed by Raya Anmol (8.67), Legend (8.17), Crusher (8.00), T-16-401 (8.00), Vangard (7.67), Vangard (7.33), Oscar (7.17), Ganyou-5 (6.33), Rainbow (6.33), Westar (6.17) and lowest in Torch (6.00) branches.

In all the 12 Brassica genotypes (Table-4.11), average highest branches loss/plant due to aphids was recorded in the genotype Peela Raya (12.05), Raya Anmol (7.8), T-16-401 (7.5), Legend (7.4), Altex (7.0), Vangard (6.5), Oscar (6.3), Crusher (5.8), Ganyou-5 (5.7), Westar (5.6), Torch (5.4) and lowest in Rainbow (5.4).

Table 4.12 show that the average highest percent branches loss was recorded in the genotype Crusher (27.78), followed by Rainbow (14.91), Oscar (11.63), Vangard (11.36), Peela Raya (10.70), Raya Anmol (10.26), Torch (10.19), Ganyou-5 (9.65), Legend (9.52), Altex (9.42), Westar (9.01) and lowest in T-16-401 (6.25). Correlation among aphids and Branches percent loss was highly significant (0.59) (Table-4.13).

Crusher was significantly highest than all the genotypes in percent branches loss, while T-16-401, being the lowest, was non-significantly different than Westar, Altex, Legend, Ganyou-5 and Torch.

4.3.6 Siliquae main raceme^{-1}

In the control treatment of all the 12 Brassica genotypes (Table-4.11), highest siliquae main raceme^{-1} was recorded in Legend (43.33), followed by Torch (39.33), Westar (39.00), Ganyou-5 (37.00), Rainbow (36.00), Oscar (34.00), Raya Anmol (31.67), Altex (31.33), Crusher (30.67), T-16-401 (30.33), Vangard (24.00) and lowest in Peela Raya (14.00).

In all the 12 Brassica genotypes (Table-4.11), average highest number of siliqua on main raceme loss due to aphids was recorded in the genotype Westar (32.67), followed by Ganyou-5 (30.45), Legend (29.78), Torch (28.56), Rainbow (28.50), Raya Anmol (24.84), T-16-401 (23.17), Altex (20.83), Oscar (20.33), Vangard (19.44), Crusher (19.44) and Peela Raya (8.61).

Results (Table-4.12) show that the average highest percent loss in the number of siliqua on main raceme due to aphids was the highest in Oscar (40.20), followed by Peela Raya (38.49), Crusher (36.59), Altex (33.51), Legend (31.28),

Torch (27.40), T-16-401 (23.63), Raya Anmol (21.58), Rainbow (20.83), Vangard (18.98), Ganyou-5 (17.72) and Westar (16.24). Correlation among aphids and siliquae mr^{-1} loss was significant (0.47) (Table-4.13).

Siliquae in Oscar was significantly different than Torch, T-16-401, Raya Anmol, Rainbow, Vangard, Ganyou-5 and Westar and non-significantly different than Peela Raya, Crusher, Altex, and Legend.

4.3.7 Leaves Plant^{-1}

In the control treatment of all the 12 Brassica genotypes (Table-4.11), the highest number of leaves plant^{-1} was recorded in Altex (41.33), followed by T-16-401 (41.33), Oscar (38.67), Vangard (36.17), Crusher (35.33), Peela Raya (34.00), Raya Anmol (33.83), Westar (30.83), Legend (30.17), Ganyou-5 (27.17), Rainbow (26.50) and lowest in Torch (26.00).

In the treated treatments of all the 12 Brassica genotype (Table-4.11), average highest leaf loss/plant due to aphids was recorded in the genotype Altex (38.28), followed by T-16-401 (36.33), Oscar (34.95), Crusher (30.67), Westar (28.61), Raya Anmol (27.72), Vangard (27.17), Peela Raya (25.06), Ganyou-5 (24.22), Rainbow (24.22), Torch (23.28) and lowest in Legend (21.83).

Results (Table-4.12) showed that the average highest percent leaf loss/plant due to aphids was recorded in the genotype Legend (27.63), followed by Peela Raya (26.31), Vangard (24.89), Raya Anmol (18.05), Crusher (13.20), T-16-401 (12.09), Ganyou-5 (10.85), Torch (10.47), Oscar (9.63), Rainbow (8.60), Altex (7.38) and lowest in Westar (7.21). Correlation among aphids and Leaves percent loss was non significant (0.32) (Table-4.13).

Legend with highest percent leaf loss was non-significantly different from Peela Raya and Vangard was significantly different than the rest of the Genotypes, which were non-significantly different form each other.

Table-4.11 Aphids density and Yield and Yield Components of 12 Brassica Genotypes (0, 5, 10 and 15 aphids/plant) during 2006-08.

Brassica Species	Genotypes	Aphids Density /Plant	Seed Yield/plant Grams	Straw Yield	Plant Height (cm)	Branches	Siliquae mr^{-1} /Plant	Leaves
Brassica napus	Westar	0.00	5.97b	24.16cd	134.1f	6.167f	39.00ab	30.83def
		70.00bc	4.83	21.31	108.1f	5.83f	33.67a	29.17cdef
		117.0a	3.92	19.89	82.10f	5.67 def	32.33 a	28.83 cde
		137.7cd	2.83	14.68	56.10 f	5.33 e	32.00 a	27.83cd
	Average	**108.2b**	**3.86abc**	**18.63ab**	**82.10e**	**5.61f**	**32.67a**	**28.61cd**
B. napus	Ganyou-5	0.00	6.09b	22.83cde	157.4cd	6.333ef	37.00bc	27.17fg
		37.83ef	4.98	20.48	131.4cd	6.00ef	33.17a	26.17def
		62.67cd	4.57	19.16	105.4cd	5.67 def	30.00 ab	23.83 f
		82.83 f	3.45	14.91	79.43 cd	5.50 de	28.17 b	22.67e
	Average	**61.11e**	**4.33a**	**18.18abc**	**105.4c**	**5.72f**	**30.45ab**	**24.22fg**
B. napus	Rainbow	0.00	5.41bc	21.00de	149.5cde	6.33ef	36.00bcd	26.50fg
		106.2a	4.05	18.57	123.5cde	5.67f	30.83ab	24.83ef
		110.0ab	3.78	17.16	97.47cde	5.50 ef	30.83 ab	24.33 ef
		200.7a	3.00	13.99	71.47 cde	5.00 e	23.83cd	23.50de
	Average	**138.9a**	**3.61abcd**	**16.57abc**	**97.47cd**	**5.39f**	**28.50abc**	**24.22fg**
B. napus	Oscar	0.00	3.62e	20.46e	144.1def	7.167de	34.00bcde	38.67ab
		49.33de	2.55	17.53	118.1def	6.67cdef	21.83de	35.67ab
		108.0ab	1.60	15.44	92.07def	6.33 cde	21.00 c	35.00 ab
		184.3ab	1.22	12.51	66.07 def	6.00 cde	18.17 ef	34.17 ab
	Average	**113.9ab**	**1.79g**	**15.16bcd**	**92.07de**	**6.33e**	**20.33bc**	**34.95b**
B. napus	Vangard	0.00	4.93cd	30.52a	140.3ef	7.333cd	24.00f	36.17bc
		74.33b	3.21	25.90	114.3ef	7.00bcde	19.83e	29.50cde
		97.00abc	1.83	20.46	88.30ef	6.50 cd	19.50 c	28.67 cde
		132.7cde	1.19	12.49	62.30 ef	6.00 cde	19.00 ef	23.33de
	Average	**101.3bc**	**2.08fg**	**19.61a**	**88.30de**	**6.50de**	**19.44cd**	**27.17def**
B. napus	Crusher	0.00	5.70bc	25.12bc	161.4c	8.00bcd	30.67de	35.33bcd
		68.50bc	3.22	20.36	135.4c	6.17def	24.00cd	33.83bc
		95.83abc	2.87	17.85	109.4c	6.00 def	18.00 c	32.17 bc
		142.0c	2.28	13.56	83.38 c	5.17 e	16.33 f	26.00cde
	Average	**102.1bc**	**2.79def**	**17.26abc**	**109.4c**	**5.78f**	**19.44cd**	**30.67c**

(Continued …)

Brassica Species	Genotypes	Aphids Density /Plant	Seed Yield/plant Grams	Straw Yield	Plant Height (cm)	Branches	Siliquae mr^{-1} /Plant	Leaves
B. napus	Torch	0.00	6.01b	24.95bc	143.4ef	6.000f	39.33ab	26.00g
		59.33cd	3.31	17.84	117.4ef	5.67f	31.17a	24.00f
		77.67bcd	2.95	15.08	91.37ef	5.33 f	28.33 ab	23.50 f
		101.2def	2.73	13.43	65.37 ef	5.17 e	26.17 bc	22.33 e
	Average	**79.39cde**	**3.00cde**	**15.45bcd**	**91.37de**	**5.39f**	**28.56abc**	**23.28g**
B. napus	Legend	0.00	4.89cd	23.34cde	157.2cd	8.167bc	43.33a	30.17efg
		69.67bc	4.02	17.57	131.2cd	7.83b	32.00a	25.50def
		125.7a	3.67	16.52	105.2cd	7.50 b	30.67 ab	23.17 f
		149.2 bc	2.15	12.14	79.23 cd	6.83 bc	26.67 bc	16.83 f
	Average	**114.8ab**	**3.28bcd**	**15.41bcd**	**105.2c**	**7.39bc**	**29.78abc**	**21.83g**
B. napus	Altex	0.00	5.54bc	27.96ab	190.8b	7.667cd	31.33de	41.33a
		73.83b	4.55	22.85	164.8b	7.17bcd	24.00cd	39.17a
		97.00abc	3.18	17.12	138.8b	7.00 bc	20.17 c	38.83 a
		101.5def	0.70	6.33	112.8 b	6.67 bcd	18.33 ef	36.83 a
	Average	**90.78bcd**	**2.81def**	**15.43bcd**	**138.8b**	**6.95cd**	**20.83bc**	**38.28a**
Average for *B. napus*		**101.16**	**3.06**	**16.86**	**101.12**	**6.12**	**25.56**	**28.14**
Brassica juncea	Raya Anmol	0.00	7.33a	24.41c	160.6c	8.667b	31.67cde	33.83cde
		27.67f	5.57	19.60	134.6c	8.00b	29.67ab	30.17cd
		57.67d	3.81	14.05	108.6c	7.83 b	27.67 b	29.17 cd
		100.7 ef	2.76	10.45	82.60 c	7.50 b	17.17 f	25.00cde
	Average	**62.00e**	**4.04ab**	**14.70cd**	**108.6c**	**7.78b**	**24.84abc**	**27.72cde**
Brassica carinata	Peela Raya	0.00	4.46de	23.41cde	205.4a	13.50a	14.00g	34.00bcde
		30.17f	2.87	16.47	179.4a	12.83a	11.50f	27.17def
		63.50cd	2.41	13.34	153.4a	12.5 a	8.333 d	26.00 def
		103.5def	1.40	7.86	127.4 a	10.83 a	6.00 g	22.00 e
	Average	**65.72de**	**2.23efg**	**12.56d**	**153.4a**	**12.05a**	**8.61d**	**25.06efg**
Brassica campestris	T-16-401	0.00	3.93e	22.42cde	178.5b	8.00bcd	30.33e	41.33a
		37.33ef	3.22	19.46	152.5b	7.67bc	27.00bc	40.00a
		54.50d	3.06	17.55	126.5b	7.50 b	21.67 c	39.33 a
		85.17 f	2.77	16.11	100.5 b	7.33 b	20.83 de	29.67 bc
	Average	**59.00e**	**3.02cde**	**17.71abc**	**126.5 b**	**7.50b**	**23.17abc**	**36.33 ab**

Means within a column followed by similar letters are non-significant from each other using LSD

Table 4.12. Aphids and Percent Losses in Yield and Yield Components in 12 Brassica Genotypes (5, 10 and 15 aphids/plant) during 2006-08.

Brassica Species	Genotypes	Aphids Density /Plant	Seed Yield/Plant grams	Straw Yield	Plant Height (cm)	Branches	Siliquae mr^{-1}	Leaves
Brassica napus	Westar	70.00bc	19.01	11.80	19.39	5.41	13.68	5.41
		117.0a	34.34	17.67	38.78	8.11	17.09	6.49
		137.7cd	52.60	39.24	58.17	13.51	17.95	9.73
	Average	**108.2b**	**35.32bcd**	**22.90ef**	**38.78a**	**9.01cd**	**16.24e**	**7.21d**
B. napus	Ganyou-5	37.83ef	18.23	10.29	16.51	5.26	10.36	3.69
		62.67cd	24.96	16.08	33.03	10.53	18.92	12.28
		82.83 f	43.35	34.69	49.54	13.16	23.87	16.57
	Average	**61.11e**	**28.85d**	**20.35f**	**33.03abcd**	**9.65cd**	**17.72e**	**10.85cd**
B. napus	Rainbow	106.2a	25.14	11.57	17.40	10.53	14.35	6.29
		110.0ab	30.13	18.29	34.79	13.16	14.35	8.18
		200.7a	44.55	33.38	52.19	21.05	33.80	11.32
	Average	**138.9a**	**33.27cd**	**21.08f**	**34.79abc**	**14.91b**	**20.83de**	**8.60d**
B. napus	Oscar	49.33de	29.56	14.32	18.05	6.98	35.78	7.76
		108.0ab	55.80	24.54	36.09	11.63	38.24	9.48
		184.3ab	66.30	38.86	54.14	16.28	46.57	11.64
	Average	**113.9ab**	**50.55ab**	**25.91def**	**36.09abc**	**11.63bc**	**40.20a**	**9.63d**
B. napus	Vangard	74.33b	34.89	**15.14**	18.53	4.55	17.36	18.44
		97.00abc	62.88	**32.96**	37.06	11.36	18.75	20.74
		132.7cde	75.86	**59.08**	55.60	18.18	20.83	35.49
	Average	**101.3bc**	**57.88a**	**35.73abcd**	**37.06ab**	**11.36bc**	**18.98e**	**24.89ab**
B. napus	Crusher	68.50bc	43.51	18.95	16.11	22.92	21.74	4.24
		95.83abc	49.65	28.94	32.22	25.00	41.30	8.95
		142.0c	60.00	46.02	48.33	35.42	46.74	26.41
	Average	**102.1bc**	**51.05a**	**31.30cdef**	**32.22abcd**	**27.78a**	**36.59ab**	**13.20cd**

(Continued …)

Brassica Species	Genotypes	Aphids Density /Plant	Seed Yield/ P grams	Straw Yield	Plant Height (cm)	Branches	Siliquae mr^{-1}	Leaves
B. napus	Torch	59.33cd	44.93	28.50	36.27	11.11	27.97	9.62
		77.67bcd	50.92	39.56	18.14	5.56	20.76	7.69
		101.2def	54.58	46.17	54.41	13.89	33.47	14.10
	Average	**79.39cde**	**50.14ab**	**38.08abc**	**36.27abc**	**10.19cd**	**27.40bcde**	**10.47cd**
B. napus	Legend	69.67bc	17.79	24.72	16.53	4.08	26.15	15.48
		125.7a	24.95	29.22	33.07	8.16	29.23	23.21
		149.2 bc	56.03	47.99	49.61	16.33	38.46	44.21
	Average	**114.8ab**	**32.92cd**	**33.98bcde**	**33.07abcd**	**9.52cd**	**31.28abcd**	**27.63a**
B. napus	Altex	73.83b	17.87	18.28	13.63	6.52	23.40	5.23
		97.00abc	42.60	38.77	27.25	8.70	35.64	6.04
		101.5def	87.36	77.36	40.88	13.04	41.49	10.88
	Average	**90.78bcd**	**49.28ab**	**44.80ab**	**27.25cd**	**9.42cd**	**33.51abc**	**7.38d**
Average for *B. napus*		**101.16**	**43.24**	**30.45**	**34.28**	**12.61**	**26.97**	**13.32**
Brassica juncea	Raya Anmol	27.67f	24.01	19.71	16.19	7.69	6.32	10.83
		57.67d	48.02	42.44	32.38	9.62	12.63	17.23
		100.7 ef	62.35	57.19	48.57	13.46	45.79	26.10
	Average	**62.00e**	**44.79abc**	**39.76abc**	**32.38abcd**	**10.26c**	**21.58cde**	**18.05bc**
Brassica carinata	Peela Raya	30.17f	35.65	29.65	12.66	4.94	17.86	20.10
		63.50cd	45.96	43.02	25.32	7.41	40.48	23.53
		103.5def	68.61	66.42	37.97	19.75	57.14	35.29
		65.72de	**50.07ab**	**46.36a**	**25.32d**	**10.70c**	**38.49ab**	**26.31a**
Brassica campestris	T-16-401	37.33ef	18.07	13.20	14.57	4.17	10.99	3.22
		54.50d	22.14	21.72	29.13	6.25	28.57	4.83
		85.17 f	29.52	28.14	43.70	8.33	31.32	28.22
	Average	**59.00e**	**23.24d**	**21.02f**	**29.13bcd**	**6.25d**	**23.63cde**	**12.09cd**

Means within a column followed by similar letters are non-significant from each other using LSD

Table-4.13 Correlation Coefficient (r) of Aphids Density with Different Yield Components

	Seed Yield (Average)	Straw Yield (Average)	Plant Height (Average)	No. of Branches (Average)	Siliqua mr^{-1} (Average)	No. of Leaves (Average)
Aphids Density	-0.483*	-0.443	-0.712**	-0.402	-0.090	-0.280
	Seed Yield % Loss	Straw % Loss	P Height % Loss	Branches % Loss	Siliqua mr^{-1} % Loss	Leaves % Loss
Aphids Density	0.520**	0.412	0.752**	0.593**	0.469*	0.317

** = significant at P<0.01); * = significant at P<0.05

4.4. APHID'S DENSITY AND BIOCHEMICAL CHARACTERISTICS OF 12 BRASSICA GENOTYPES UNDER SCREENHOUSE CONDITIONS

The Table 4.14 revealed that among all the Brassica genotypes grown under screenhouse conditions infested with 0, 5, 10 and 15 aphids/plant at flower bud initiation stage highest average aphids density was observed on the genotype Rainbow (138.9), followed by Legend (114.8), Oscar (113.9), Westar (108.2), Crusher (102.1), Vangard (101.3), Altex (90.78), Torch (79.39), Peela Raya (65.72), Raya Anmol (62.0), Ganyou-5 (61.11) and lowest in T-16-401 (59.0) aphids per plant. Among the *B. napus* group Ganyou-5 had the lowest aphid's density per plant.

Among all the 12 Brassica genotypes average aphids density ranged from 59.00 to 138.9 with a mean value of 98.95 aphids per plant.

Statistically Rainbow had the highest numbers of aphids per plant which was significantly different than Torch, Peela Raya, Raya Anmol, Ganyou-5 and T-16-401 but non-significantly different than Legend, Oscar, Westar, Crusher, Vangard and Altex. T-16-401 had the lowest aphid's density /plant followed by Ganyou-5, non-significantly different than all the other Genotypes except Rainbow.

4.4.1 Oil Contents (%)

Results Table 4.14 showed that in the untreated control treatment of all the 12 Brassica genotypes the highest oil contents were recorded in the genotype Torch (47.98) followed by Westar (47.32), Legend (45.07), Rainbow (44.67), Ganyou-5 (43.53), Oscar (44.60), Crusher (44.53), Raya Anmol (40.20), Vangard (39.70), Altex (40.13), Peela Raya (39.70), and lowest in T-16-401 (38.27).

Table (4.15) show results of all the 12 genotypes artificially infested with 5, 10 and 15 aphids. On average basis the highest oil content were found in the genotype Torch (47.93) followed by Westar (45.07), Legend (44.90), Rainbow (43.07), Ganyou-5 (42.93), Oscar (41.97), Crusher (41.80), Westar (45.07), Raya Anmol (39.87), Vangard (39.00), Altex (38.77), Peela Raya (38.57) and lowest in T-16-401 (37.27). Correlation among aphids and oil contents was 0.195 (Table-4.18).

Table-4.17 shows the average percent losses in the chemical constituents of all the 12 Brassica genotypes. The result show that the highest average percent losses in Oil contents were recorded in Crusher (6.13), followed by Oscar (5.90), Westar (4.76), Rainbow (3.59), Altex (3.40), Peela Raya (2.85), T-16-401 (2.62), Vangard (1.76), Ganyou-5 (1.37), Raya Anmol (0.83), Legend (0.38) and lowest in Torch (0.10). Correlation among aphids and loss in oil contents was negative and non-significant (-0.027) (Table-4.18).

Among all the 12 Brassica genotypes average oil% in the control (Table 4.14) ranged from 38.27 to 47.98 with a mean value of 43.13%; in the infested treatment (Table 4.15) ranged from 37.27-47.93 with a mean value of 41.76 and average percent losses (Table 4.17) ranged from 0.10 to 6.13 with a mean value of 2.81%.

Statistical analysis of the data (Table-4.14) shows that oil contents were significantly highest in Torch than all other genotypes. Westar was non-significantly different than Legend and Rainbow and significantly different than the rest of the genotypes. Ganyou-5, Oscar and Crusher were significantly different than Raya Anmol, Vangard, Peela Raya, Altex and T-16-401.

4.4.2 Protein contents (%)

Table 4.14 shows the results of the chemical constituents of the untreated control treatments of all the 12 genotypes. The results show that the highest protein contents were found in T-16-401 (27.98) followed by Peela Raya (26.33), Raya Anmol (25.63), Altex (25.27), Crusher (24.38), Torch (24.37), Vangard (24.02), Oscar (23.95) Legend (23.58), Westar (23.02), Rainbow (22.77), and lowest in Ganyou-5 (22.45).

Table 4.15 shows the results of all the 12 Brassica genotypes artificially infested with 5, 10 and 15 aphids. The results showed that protein content was highest in the seeds of Oscar (29.83), T-16-401 (29.70), Peela Raya (29.37), Crusher (29.07), Altex (28.53), Vangard (28.43), Rainbow (28.17), Raya Anmol (26.67), Legend (26.07), Westar (25.77), and Torch (25.73) and lowest in Ganyou-5 (24.70).

Comparison of protein% of all the 12 Brassica genotypes untreated control treatments (Table-4.14) with the artificially infested treatments of all the genotypes (Table-4.16) showed that protein% increased with aphid infestation in all the 12 Brassica genotypes. Results in (Table-4.17) show the actual average losses/gain in the chemical composition of all the 12 Brassica genotypes. Highest average percent increase in protein contents was recorded in Oscar (24.57) followed by Rainbow (23.70), Crusher (19.22), Vangard (18.37), Altex (12.91), Westar (11.93), Peela Raya (11.53), Legend (10.55), Ganyou-5 (10.02), T-16-401 (6.15), Torch (5.59), and lowest in Raya Anmol (4.04). Correlation among aphids and increase in protein contents was non-significant (0.347) (Table-4.18).

Highest protein contents were recorded in Oscar, which was non-significant differently than T-16-401, Peela Raya, Crusher, Altex, Vangard and Rainbow and significantly different than Westar, Torch, Legend and Ganyou-5.

Among all the 12 Brassica genotypes average protein contents in the untreated control (Table-4.14) ranged from 22.45 to 27.98 with a mean value of 25.22; average change/increase due to infestation of aphids in protein contents (Table-4.16) ranged from 24.70 to 29.83 with a mean value of 27.27 and average percent gain in protein contents (Table-4.17) ranged from 5.88 to 51.04%.

4.4.3 Glucosinolate (μ mg^{-1}) Contents

In the untreated control of all the 12 genotypes (Table-4.14) the highest glucosinolate was recorded in T-16-401 (180.9) followed by Altex (157.8), Peela Raya (129.9), Raya Anmol (99.5), Westar (88.22), Vangard (86.65), Oscar (83.82), Torch (83.47), Crusher (75.95), Legend (72.82), Rainbow (71.35) and lowest in Ganyou-5 (71.17).

Results (Table-.4.15) of all the 12 Brassica genotypes artificially infested with 5, 10 and 15 aphids/plant showed that the highest glucosinolate contents were recorded in the genotype T-16-401 (167.0), followed by Altex (164.1), Peela Raya (136.6), Vangard (106.7), Raya Anmol (105.0), Westar (98.90), Rainbow (97.80), Torch (93.03), Oscar (92.87), Crusher (89.17), Ganyou-5 (64.30) and lowest in Legend (61.90). Correlation

among aphids and glucosinolates in the seeds was non-significant negative (-0.204) (Table-4.18).

Significantly the highest glucosinolates were found in T-16-401, which were non-significantly different than Altex. Peela Raya was significantly different than Vangard and Raya Anmol, which were non-significantly different than Westar, Rainbow, Torch, Oscar and Crusher. Ganyou-5 had significantly the lowest glucosinolates but non-significantly different than Legend.

Results (Table-4.17) showed that the highest percent gain in glucosinolate was recorded in the seeds of Rainbow (37.07), followed by Vangard (23.10), Crusher (17.40), Westar (12.11), Torch (11.46), Oscar (10.79), Raya Anmol (5.53), Peela Raya (5.18), Altex (3.99), and highest losses glucosinolates in Legend (15.00), Ganyou-5 (9.65) and T-16-401 (7.67) in the order. Correlation among aphids and Percent (loss/increase) in glucosinolates contents was non-significant (0.440) (Table-4.18).

Among all the 12 Brassica genotypes average glucosinolates in the untreated control (Table-4.14) ranged from 71.17 to 180.90 with a mean value of 126.04%; the average losses due to aphids in glucosinolates (Table 4.15) ranged from 61.90 to 167.00 with a mean value of 114.45% and average percent loss in glucosinolates (Table 4.17) ranged from 7.67 to 15.00 and gain from 3.99-37.07%.

4.4.4. Moisture Contents (%)

In the uninfested control treatment of all the 12 Brassica genotypes the highest moisture contents were recorded in the seeds of Brassica genotype Torch (6.97) followed by Oscar (6.50 Rainbow) (5.97), T-16-401 (5.97), Westar (5.93), Vangard (5.90), Crusher (5.75), Legend (5.43), Altex (5.33), Ganyou-5 (5.02), Raya Anmol (4.93) and lowest in Peela Raya (3.20).

Results (Table-4.14) of all the 12 Brassica genotypes artificially infested with 5, 10 and 15 aphids/plant, the highest moisture contents were recorded in the seeds of Brassica genotype Oscar (6.43) followed by Rainbow (6.30), Torch (6.23), Westar (6.07), Crusher (5.80), Legend (5.70), Altex (5.40), Vangard (5.17), Ganyou-5 (4.87), T-16-401

(4.70), Raya Anmol (4.53) and lowest in Peela Raya (2.83). Correlation among aphids and moisture contents in the seeds was non significant (0.397) (Table-4.18).

Highest percent loss in moisture contents (Table-4.17) with aphids infestation was recorded in the seed of T-16-401 (21.27), followed by Vangard (12.43), Peela Raya (11.46), Torch (10.57), Raya Anmol (8.05), Ganyou-5 (3.05), Oscar (1.03) and gain in Rainbow (5.53), Legend (4.97), Westar (2.25), Altex (1.31) and lowest in Crusher (0.87) in the order (Table-4.14). Correlation among aphids and moisture in the seeds was non significant (0.397) (Table-4.18).

Moisture in the uninfested control treatment (Table-4.14) ranged from 3.20 to 6.97 with a mean value of 5.08%; average losses due to aphids in moisture (Table-4.15) ranged from 2.83 to 6.43 with a mean value of 4.63% and average loss in moisture content (Table-4.17) ranged from 1.03 to 21.27 and gain from 0.87 to 5.53.

Highest moisture contents were recorded in Oscar, which was non-significantly different than Rainbow, Torch and Westar. Peela Raya had significantly the lowest moisture contents.

4.4.5 Oleic Acid %

Results (Table-4.14) show that in the uninfested control treatment of all the 12 Brassica genotypes the highest oleic acid were found in Ganyou-5 (68.03), followed by Crusher (56.62), Rainbow (56.13), Legend (56.12), Oscar (55.9), Westar (55.33), Vangard (54.73), Torch (48.22), Raya Anmol (38.14), Altex (36.33), Peela Raya (32.53) and lowest in T-16-401 (31.77).

Table (4.15) shows that in artificially infested with 5, 10 and 15 aphids/plant all the 12 Brassica genotypes the highest oleic acid % was recorded in the seeds of genotype Ganyou-5 (67.07), Westar (58.50), Vangard (56.90), Oscar (53.83), Crusher (53.73), Legend (53.30), Rainbow (51.50), Torch (48.60), Raya Anmol (38.27), T-16-401 (38.07), Altex (36.60) and lowest in Peela Raya (33.70). Correlation among aphids and average oleic acid contents was non-significant (0.209) (Table-4.18).

Results show that the highest percent gain in oleic acid (Table-4.17) due to aphids, recorded in the seed of brassica was in T-16-401 (19.82) followed by Westar (5.73), Vangard (3.96), Peela Raya (3.60), Torch (0.79), Altex (0.74), Raya Anmol (0.33) and losses in Rainbow (8.25), Crusher (5.10), Legend (5.02), Oscar (3.70) and Ganyou-5 (1.42) in the order. Correlation among aphids and loss/gain in oleic acid contents was negative and non-significant (-0.001) (Table-4.18).

Among all the 12 Brassica genotypes average oleic acid in the uninfested control treatment (Table-4.14) ranged from 31.77 to 68.03 with a mean value of 49.90%; average losses due to aphids in oleic acid (Table-4.15) ranged from 33.70 to 67.07 with a mean value of 50.39% and average percent losses in oleic acid (Table-4.17) ranged from 1.42 to 8.25 and gain from 0.33-19.82.

Significantly the highest amount of oleic acid was found in Ganyou-5, followed by Westar which was non-significantly different than Vangard, Crusher, Oscar and Legend. Peela Raya had the lowest oleic acid which was non-significantly different than Altex. Correlation among aphids and oleic acid in the seeds was 0.209 (Table-4.15).

4.4.6 **Linolenic Acid** (%)

In the control treatment (Table-4.14) results show that in all the 12 Brassica genotypes the highest Linolenic Acid were found in Raya Anmol (12.43), followed by Peela Raya (12.13), T-16-401 (12.0), Altex (11.57), Rainbow (10.25), Crusher (10.18), Torch (9.72), Oscar (9.72), Ganyou-5 (9.28), Legend (9.07), Westar (7.87), and lowest in Vangard (7.77).

Results in Table-4.15 show that in all the 12 Brassica genotypes infested with 5, 10 and 15 aphids/plant the highest Linolenic Acid was found in Peela Raya (12.37) followed by T-16-401 (12.13), Altex (12.00), Raya Anmol (11.37), Crusher (10.13), Torch (10.03), Oscar (9.83), Rainbow (9.80), Ganyou-5 (9.03), Westar (8.97), Legend (8.83) and lowest in Vangard (8.13).

The highest gain in linolenic acid (Table-4.14) due to aphids recorded in the seed of brassica was in Westar (13.93) followed by Vangard (4.68), Altex (3.72), Torch (3.22),

Peela Raya (1.95), Oscar (1.17), T-16-401 (1.11) and losses of Linolenic acid in Raya Anmol (8.55), Rainbow (4.39), Ganyou-5 (2.66), Legend (2.61), Crusher (0.46) in the order. Correlation among aphids and loss/gain in oleic acid contents was negative and non-significant (-0.001) (Table-4.15).

Among all the 12 Brassica genotypes average linolenic acid in the uninfested control treatment (Table-4.14) ranged from 7.77 to 12.43 with a mean value of 10.10%; average losses due to aphids in linolenic acid (Table-4.15) ranged from 8.13 to 12.37 with a mean value of 10.25% and average percent losses in linolenic acid (Table-4.14) ranged from 0.46 -8.55 and gain from 1.11-13.93.

Peela Raya had the highest linolenic acid which was non-significantly different than T-16-401 Altex and Raya Anmol. This was followed by Crusher, which was non-significantly different than Torch, Oscar, Rainbow, Ganyou-5, Westar and Legend. Vangard had the lowest linolenic acid which was non-significantly different than Legend, Westar and ganyou-5.

4.4.7 Erucic Acid

Results (Table-4.14) show that in the control treatment of all the 12 Brassica genotypes the highest erucic acid content were found in Torch (56.9), followed by T-16-401 (55.8), Peela Raya (55.03), Altex (51.67), Raya Anmol (51.1), Vangard (44.17), Westar (41.53), Oscar (40.62), Rainbow (37.6), Crusher (35.73), Legend (34.43) and lowest in Ganyou-5 (19.4).

Table (4.15) shows that in all the 12 Brassica genotypes artificially infested with 5, 10 and 15 aphids, erucic acid was highest in the seeds of genotype Torch (55.83) followed by Peela Raya (52.80), Altex (51.17), T-16-401 (50.67), Oscar (49.83), Raya Anmol (49.40), Rainbow (47.63), Westar (46.13), Legend (45.23), Vangard (43.83), Crusher (42.60) and lowest in Ganyou-5 (22.00).

Highest gain in erucic acid (Table-4.15) due to aphids, recorded in the seeds of Brassica genotypes was in Legend (31.38), Rainbow (26.68), Oscar (22.68), Crusher (19.23), Ganyou-5 (13.40) Westar (11.08) and losses in T-16-401 (9.20), Peela Raya

(4.05), Raya Anmol (3.33), Torch (1.87), Altex (0.97), Vangard (0.76) in the order. Correlation among aphids and loss/gain in erucic acid contents was significant (0.453) (Table-4.18).

Torch had the highest erucic acid contents followed by non-significant Peela Raya, Altex and T-16-40. Ganyou-5 had significantly the lowest erucic acid contents, followed was non-significantly different Crusher, Vangard, Legend, Westar and Rainbow. Correlation among aphids and erucic acid in the seeds was non significant 0.052 (Table-4.18).

Among all the 12 Brassica genotypes average erucic acid in the uninfested control treatment (Table-4.14) ranged from 19.40 to 56.90 with a mean value of 38.15%; average losses due to aphids in erucic acid (Table-4.15) ranged from 22.00 to 55.83 with a mean value of 38.92% and average losses in erucic acid (Table-4.17) ranged from 0.76 to 9.20 and gain from 11.08 to 31.38.

Table 4.14 Aphids density and Biochemical Characteristics of 12 Brassica Genotypes in Untreated Control during 2006-08.

Brassica Species	Genotypes	Aphids /Plant	Oil Contents	Protein	GSL	Moisture	Oleic Acid	Linolenic Acid	Erucic Acid
Brassica napus	Westar	0.00	47.32a	23.02b	88.22de	5.933bc	55.33b	7.87d	41.53de
B. napus	Ganyou-5	0.00	43.53b	22.45b	71.17f	5.02d	68.03a	9.28bc	19.40g
B. napus	Rainbow	0.00	44.67b	22.77b	71.35ef	5.97bc	56.13b	10.25b	37.60ef
B. napus	Oscar	0.00	44.60b	23.95ab	83.82def	6.50ab	55.90b	9.72bc	40.62de
B. napus	Vangard	0.00	39.70c	24.02ab	86.65def	5.90bc	54.73b	7.77d	44.17d
B. napus	Crusher	0.00	44.53b	24.38ab	75.95ef	5.75bcd	56.62b	10.18b	35.73f
B. napus	Torch	0.00	47.98a	24.37ab	83.47def	6.97a	48.22c	9.72bc	56.90a
B. napus	Legend	0.00	45.07b	23.58b	72.82ef	5.43cd	56.12b	9.07c	34.43f
B. napus	Altex	0.00	40.13c	25.27ab	157.8b	5.33cd	36.33de	11.57a	51.67bc
Average for *B. napus*		0.00	44.17	23.76	87.92	0.00	54.16	9.49	40.23
Brassica juncea	Raya Anmol	0.00	40.20c	25.63ab	99.50d	4.93d	38.14d	12.43a	51.10c
Brassica carinata	Peela Raya	0.00	39.70c	26.33ab	129.9c	3.20e	32.53ef	12.13a	55.03abc
Brassica campestris	T-16-401	0.00	38.27c	27.98a	180.9a	5.97bc	31.77f	12.00a	55.80ab

Means within a column followed by similar letters are non-significant from each other using LSD

Table 4.15 Aphids density and Biochemical Characteristics of 12 Brassica Genotypes infested with 5, 10, 15 aphids/plant during 2006-08.

Brassica Species	Genotypes	Aphids /Plant	Oil Contents	Protein	GSL	Moisture	Oleic Acid	Linolenic Acid	Erucic Acid
Brassica napus	Westar	108.2 b	45.07 ab	25.77 d	98.90 cd	6.067 abc	58.50 b	8.967 cd	46.13cde
B. napus	Ganyou-5	61.11 e	42.93 bcd	24.70 d	64.30 e	4.867 fgh	67.07 a	9.033 cd	22.00 f
B. napus	Rainbow	138.9 a	43.07 bc	28.17 abc	97.80 cd	6.300 ab	51.50 de	9.800 c	47.63bcde
B. napus	Oscar	113.9 ab	41.97 bcde	29.83 a	92.87 cd	6.433 a	53.83 cd	9.833 bc	49.83 bcd
B. napus	Vangard	101.3 bc	39.00 efg	28.43 ab	106.7 c	5.167 efg	56.90 bc	8.133 d	43.83 e
B. napus	Crusher	102.1 bc	41.80 cdef	29.07 a	89.17 d	5.800 bcd	53.73 cd	10.13 bc	42.60 e
B. napus	Torch	79.39 cde	47.93 a	25.73 d	93.03 cd	6.233 abc	48.60 e	10.03 bc	55.83 a
B. napus	Legend	114.8 ab	44.90 abc	26.07 cd	61.90 e	5.700 cde	53.30 d	8.833 cd	45.23 de
B. napus	Altex	90.78 bcd	38.77 fg	28.53 ab	164.1 a	5.400 def	36.60 fg	12.00 a	51.17 abc
Average for B. napus		**101.16**	**42.83**	**27.37**	**96.53**	**5.77**	**53.34**	**9.64**	**44.92**
Brassica juncea	Raya Anmol	62.00 e	39.87 defg	26.67 bcd	105.0 cd	4.533 h	38.27 f	11.37 ab	49.40 bcd
Brassica carinata	Peela Raya	65.72 de	38.57 g	29.37 a	136.6 b	2.833 i	33.70 g	12.37 a	52.80 ab
Brassica campestris	T-16-401	59.00 e	37.27 g	29.70 a	167.0 a	4.700 gh	38.07 f	12.13 a	50.67 bcd

Means within a column followed by similar letters are non-significant from each other using LSD

Table 4.16 Aphids Density and Losses/Gain in Biochemical Characteristics of 12 Brassica Genotypes 2006-08.

Brassica Species	Genotypes	Aphids /Plant	Oil Contents	Protein	GSL	Moisture	Oleic Acid	Linolenic Acid	Erucic Acid
Brassica napus	Westar	108.2 b	2.25	-2.75	-10.68	-0.13	-3.17	-1.10	-4.60
B. napus	Ganyou-5	61.11 e	0.60	-2.25	6.87	0.15	0.96	0.25	-2.60
B. napus	Rainbow	138.9 a	1.60	-5.40	-26.45	-0.33	4.63	0.45	-10.03
B. napus	Oscar	113.9 ab	2.63	-5.88	-9.05	0.07	2.07	-0.11	-9.21
B. napus	Vangard	101.3 bc	0.70	-4.41	-20.02	0.73	-2.17	-0.36	0.34
B. napus	Crusher	102.1 bc	2.73	-4.69	-13.22	-0.05	2.89	0.05	-6.87
B. napus	Torch	79.39 cde	0.05	-1.36	-9.56	0.74	-0.38	-0.31	1.07
B. napus	Legend	114.8 ab	0.17	-2.49	10.92	-0.27	2.82	0.24	-10.80
B. napus	Altex	90.78 bcd	1.36	-3.26	-6.30	-0.07	-0.27	-0.43	0.50
Brassica juncea	Raya Anmol	62.00 e	0.33	-1.04	-5.50	0.40	-0.13	1.06	1.70
Brassica carinata	Peela Raya	65.72 de	1.13	-3.04	-6.73	0.37	-1.17	-0.24	2.23
Brassica campestris	T-16-401	59.00 e	1.00	-1.72	13.87	1.27	-6.30	-0.13	5.13

Means within a column followed by similar letters are non-significant from each other using LSD
(-) sign indicates gain in the content

Table 4.17 Aphids Density and Biochemical Characteristics of 12 Brassica Genotypes (Percent Losses/Gain) 2006-08.

Brassica Species	Genotypes	Aphids /Plant	Oil Contents	Protein	GSL	Moisture	Oleic Acid	Linolenic Acid	Erucic Acid
Brassica napus	Westar	108.2 b	4.76	-11.93	-12.11	-2.25	-5.73	-13.93	-11.08
B. napus	Ganyou-5	61.11 e	1.37	-10.02	9.65	3.05	1.42	2.66	-13.40
B. napus	Rainbow	138.9 a	3.59	-23.70	-37.07	-5.53	8.25	4.39	-26.68
B. napus	Oscar	113.9 ab	5.90	-24.57	-10.79	1.03	3.70	-1.17	-22.68
B. napus	Vangard	101.3 bc	1.76	-18.37	-23.10	12.43	-3.96	4.68	0.76
B. napus	Crusher	102.1 bc	6.13	-19.22	-17.40	-0.87	5.10	0.46	-19.23
B. napus	Torch	79.39 cde	0.10	-5.59	-11.46	10.57	-0.79	-3.22	1.87
B. napus	Legend	114.8 ab	0.38	-10.55	15.00	-4.97	5.02	2.61	-31.38
B. napus	Altex	90.78 bcd	3.40	-12.91	-3.99	-1.31	-0.74	-3.72	0.97
Brassica juncea	Raya Anmol	62.00 e	0.83	-4.04	-5.53	8.05	-0.33	8.55	3.33
Brassica carinata	Peela Raya	65.72 de	2.85	-11.53	-5.18	11.46	-3.60	-1.95	4.05
Brassica campestris	T-16-401	59.00 e	2.62	-6.15	7.67	21.27	-19.82	-1.11	9.20

Means within a column followed by similar letters are non-significant from each other using LSD
(-) sign indicate gain in the contents

Table-4.18. Correlation Coefficient (r) of Aphids Density with Different Biochemical Characteristics during 2006-08.

	Oil % Contents	Protein %	GSL u mol/g	Moisture %	Oleic Acid	Linolenic Acid	Erucic Acid
Aphids Density	0.195	-0.001	-0.204	0.397	0.209	-0.334	0.052
	Oil % Loss	Protein % Loss/Gain	GSL Loss/Gain	Moisture Loss/Gain	Oleic Acid Loss/Gain	Linolenic Acid Loss/Gain	Erucic Acid Loss/Gain
Aphids Density	-0.027	0.347	0.440	-0.175	-0.001	0.014	0.453*

* = significant at P<0.05

CHAPTER-V

DISCUSSION

5.1 RELATIVE ABUNDANCE OF APHIDS POPULATION ON DIFFERENT BRASSICA GENOTYPES

The aphid frequently reported on brassica in this area is Mustard aphid, *Lipaphis erysimi* (Kaltenbach) (Agarwala and Datta, 1999; Siraj-ud-din, 2000). Aphids appeared on different Brassica genotypes in the 1st and 2nd week of February (2008) and (2007) respectively.

During cropping season 2006-07 aphids' population started appearing during the 2nd week of February 2007 and reached the maximum in third week of February 2007. In 2007-08 aphids population started appearing during the first week of February and reached at maximum level during the third week of February. After that, its population decreased gradually, until it reached at minimum level during the 4th week of March during 2007 and second week of March during 2008. Higher aphids' density was recorded during 2008 than 2007, mainly due to the higher temperature and lower relative humidity. Aslam et al*.* (2005) indicated that aphids' population in brassica fluctuated over time. During the last week of January aphids' population started and reached to maximum during the third week of February, and declined during the second week of March. The difference could be due to variation in temperature and overall weather (Annex. 9.1 & 9.2).

The present results agree with that of Amjad (2007). He recorded the 2nd and 3rd week of February as the most suitable time for the propagation of aphid population (136.47 per 10 cm inflorescence) and (134.33 per 10 cm inflorescence), respectively. The observation on seasonal incidence of aphids are in conformity with findings of Choudhury and Pal (2009) who observed that aphids infestation was at peak during 2nd and 4th weak of February. Amer et al. (2009) recorded highest aphid's population during last week of February to second week of March that is in conformity with the present findings.

5.1.2 Aphids Density and Relative Resistance in 12 Brassica Genotypes

From the perusal of results of experimental trials on the performance of Brassica genotypes against aphids it appears that no genotype was completely free of aphid's infestation. All the genotypes varied in degree of aphids' density and showed different response towards holding aphids' infestation under the prevailing field and weather conditions.

Paula *et al*. (1995) observed that net reproduction rate and population increase of cabbage aphid was low on resistant than susceptible varieties. Cornell University (2006) suggests that increase in the level of glucosinolates decrease the aphids population. Vangard had comparatively higher amounts of glucosinolates in the seeds and also the lowest number of aphids (12.84 aphids/ plant); followed by Crusher (18.42), Altex (21.57), Westar (23.41) and Peela Raya (23.55). Based on aphids population under field conditions Vangard is considered relatively tolerant to aphids, while, T-16-401 (24.89), Torch (25.39), Rainbow (26.86), Raya Anmol (27.57) and Oscar (30.47) had moderate level of aphid's density. Legend (37.94) and Ganyou-5 (34.87) had highest mean number of aphids. Therefore, Legend and Ganyou-5 are termed as susceptible genotypes to aphids, under prevailing conditions.

Our results are in concurrence with those of Jatoi et al. (2002). They found Oscar as intermediately susceptible and Crusher relatively resistant among 22 cultivars of *Brassica napus* against turnip aphid, *Lipaphis erysimi* Kalt. Mamun et al. (2010) concluded that the resistant or less susceptible variety had lower aphid infestation. Vangard had less aphid population, which means it has some degree of resistance as compared to the other genotypes. Sarwar et al. (2004) reported per plant aphid's population for Westar (98.40), Rainbow (44.92) and Oscar (76.77) as compared to 23.41, 26.86 and 30.47 aphids/plant in the present study, respectively confirming similar pattern. Aslam et al. (2005) observed that none of the variety was completely free from aphid's infestation among the ten tested canola Genotypes. Maximum mean aphid population was recorded on con-I (57.8), followed by Oscar (55.9 aphids), Con-III (50.5 aphids), Dunkeld (48.9), Shiralee (45.5 aphids), Westar

(41.9 aphids), Con-II (41.6 aphids), Rainbow (36.9 aphids) and Abaseen (35.7 aphids). In comparison we had in our study 30.47 aphids/plant on Oscar, 23.41 aphids/ plant on Westar and 26.86 aphids/plant on Rainbow, respectively, showing perfect parity with results of Aslam et al. (2005). Khan and Begum (2005) concluded from an experiment on 6 canola Genotypes that none of the variety was resistant/ tolerant to the attack of aphids. Aphid population started in 3rd week of December and reached to its peak in 4th week of February due to optimum environmental temperature. The results are similar to ours except the difference in start and end date of aphid's population due to weather conditions. Malik (1988) tested resistance of *B. juncea*, *B. napus*, *B. nigra* and 3 cultivars of *B. campestris* against *L. erysimi* in India during 1973-75. All of the tested cultivars were found susceptible to the attack of *L. erysimi*. This is also in conformity with our results that none of the genotype showed absolute resistance against aphids.

Our result disagrees with Choudhury and Pal (2009). They stated that *B. campestris* varieties as a group harbored relatively higher populations of aphid than *B. juncea* varieties. In our case *B. juncea* group harboured more aphids than *B. campestris*, however the difference was non significant. Also, our results were contrary to those of Gill and Bakhetia (1985). They found fewer aphids on all *B. napus* than on *B. campestris*. Our results showed more aphids on some genotypes in *B. napus* than *B. campestris*. The difference in the results could be due to the difference in the tested varieties/genotypes and ecological conditions for the studies.

Amjad et al. (1999) found significantly high reproduction on *B. campestris* and *B. napus* than *B. juncea* and *B. carinata*. In our results *B. juncea* had more aphids population than *B. napus*, *B. campestris* and *B. carinata*, however, the difference among the aphid population among the different groups was non significant. Amer (2009) found all the genotypes evaluated susceptible against two aphid species (*B. brassicae* and *L. erysimi*.) that were significantly similar in Population. Our result also agree with Vekaria and Patel (2000) who found no genotype immune against any of the forty promising brassica and allied genotypes against mustard aphid, *Lipaphis erysimi* (Kaltenbach). However, our results do not agree with their

statement that Mustard genotypes belonging to *B. campestris* group were more susceptible to aphid than that of *B. juncea*. Our results agree with Amjad (2007) who found *B. napus* (var. Bubul-98) susceptible to *B. campestris* (var. Peeli Sarson).

Khattak and Hamed (1993) reported that susceptibility of a crop to insect pest depends on multiple factors including biotic, a-biotic and ecological. This suggests that, additional factors are needed to be taken into consideration before labeling a variety resistant or susceptible. The most important amongst these could be the crop genetic potential, insect species and the prevailing environment. Aphid's resistance in Brassica crops has a long way to go. More research work is required to find out the resistance factors and its mechanism (Bhatia et al. 2011).

5.1.3. APHIDS DENSITY AND YIELD COMPONENTS IN 12 BRASSICA GENOTYPES UNDER FIELD CONDITIONS

5.1.3.1 Plant Height (cm)

The plant height of the 12 varieties/genotypes ranged from 150.4 to 214.3 cm with a mean value of 182.35 cm. Farhatullah et al. (2004) reported plant height 137.0 and 156.7cm for Altex and Oscar as compared to 195.1 and 173.4cm in our study, respectively. Rahman et al. (2009) observed mean value for Altex (104.7) and Oscar (98.72cm) much lower than the values (195.1 cm and 173.4 cm) recorded in the present study. Malik et al. (2004) reported maximum plant height (212.0 cm) with the application of 150 kg/ha of Sulphur and minimum (185.6 cm) in Canola variety ZAFAR-2000. Their results are similar to ours (150.4 to 214.3 cm). Khan and Begum (2005) found plant height of 118.5 cm in Rainbow, which is much lower than 165.8 cm found in the present study. According to Khan et al. (2008), plant height of different Brassica genotypes ranged from 140.9 to 208.2 cm, with mean value of 182.2cm. The present results are comparable to theirs. They found plant height for Rainbow (141 cm) which is lower than in our study (165.8 cm). Shah et al. (2007) recorded plant height (182.5cm) in new hybrid Durr-e-NIFA, developed from an Australian canola genotype 'Dunkeld' and a local rapeseed mutant variety 'Abasin 95'. Their results are similar to ours. Anjum et al. (2005) reported values of

plant height for Westar, Rainbow, Oscar and Peela Raya as 73.47, 63.87, 60.13 and 258.2cm, respectively as compared to 150.4, 165.8, 173.4 and 214.3 cm, respectively, in the present study. Cheema et al. (2001) reported plant height values for Westar, Rainbow and Oscar as 215.3, 177.9 and 185.5cm respectively as compared to 150.4, 165.8 and 173.4cm, respectively, in the present study.

5.1.3.2 Primary Branches

The primary branches recorded on all the tested genotypes ranged from 6.94 to 19.20 with a mean value of 13.07. According to Khan et al. (2008) the number of primary branches ranged from 5.5 to 14.6 with a mean value of 8.1, which is similar to the present results, except for Peela Raya (19.20 braches). The numbers of primary branches for Rainbow were 8.08 and 8.05 in our and their study, respectively. Anjum et al. (2005) reported the number of primary branches for Westar, Rainbow, Oscar and Peela Raya as 7.76, 7.0, 8.0 and 8.3 as compared to 6.94, 8.08, 8.25 and 19.20 branches in the present work, respectively.

5.1.3.3 Siliquae main raceme^{-1}

The number of siliqua raceme^{-1} of different genotypes ranged from 20.76 to 70.20 siliqua with a mean value of 45.48 siliqua. Khan et al. (2008) reported values for siliqua per raceme 68.3 to 94.1 with mean value of 82.2 siliqua, which are much higher than our results. They reported value for siliqua per raceme for Rainbow as 71.0. This is much higher than (58.28) in our studies for the same genotype.

5.1.3.4 Siliqua Length

The siliqua length of different genotypes ranged from 4.02 to 8.31 cm with a mean value of 6.16 cm. Ahmad et al. (2008) found that siliqua length for Altex, Oscar and Rainbow as 6.7, 5.5 and 5.9 cm as compared to the present findings of 4.0, 6.9 and 6.8cm, respectively. Rahman et al. (2009) reported siliqua length of 5.5 and 5.3 cm for Altex and Oscar as compared to 4.02, 6.9 cm, respectively in the present study. Swati (2005) reported siliqua length 3.70, 5.50, 5.70, 3.42 and 3.30 cm for Oscar, Crusher, Torch, Raya Anmol and T-16-401, as compared to 6.92, 6.12, 6.94,

4.41 and 4.69 cm, respectively, in the present study. Swati (2005) reported siliqua length as 5.50 cm for Crusher compared to 6.12 cm in the present study. Khan et al. (2008) recorded siliqua length for various brassica populations from 3.8 to 6.8 cm with a mean value of 5.7 cm, which is close to our results. Their value for Rainbow was 5.0 cm as compared to 6.8cm found in the present work.

5.1.3.5 Seed Siliqua^{-1}

The number of seed siliqua^{-1} of different genotypes ranged from 9.38 to 23.57 with a mean value of 16.475. Rahman et al. (2009) reported number of seeds siliqua^{-1} for Altex as 22.85 and Oscar as 21.37. Farhatullah et al. (2004) reported 17.53 seed/siliqua for Altex and 17.67 for Oscar as compared to 9.99 and 23.57, respectively, in the present study. Swati (2005) reported 20.0, 17.8, 20.6, 10.0 and 12 number of seed siliqua^{-1} for Oscar, Crusher, Torch, Raya Anmol and T-16-401, as compared to 23.57, 15.57, 13.55, 10.04 and 9.74 seeds siliqua^{-1}, respectively, in the present study. Khan and Begum (2005) found 21.45 seeds siliqua^{-1} in Rainbow as compared to 17.11 in the present study. According to Malik et al. (2004) the number of seeds siliqua^{-1} ranged from 19.63 to 24.67, which is comparable to our results. Anjum et al. (2005) reported seed siliqua^{-1} for Westar, Rainbow, Oscar and Peela Raya as 22.93, 22.1, 24.6 and 19.7 as compared to 16.35, 17.11, 23.57 and 11.58 in the present work, respectively. Cheema et al. (2001) reported seeds siliqua^{-1} for Westar, Rainbow and Oscar as 26.4, 22.3 and 24.4 as compared to 16.35, 17.11 and 23.57 seeds, respectively in the present study.

5.1.3.6 1000 Seeds Weight (grams)

Weight of 1000-grain of the different genotypes ranged from 3.37 to 4.80 with a mean value of (4.085 g). Rahman et al. (2009), Farhatullah et al. (2004) and Ahmad et al. (2008) reported that 1000 seed weight for Altex and Oscar as 2.55 and 3.17grams; 3.00 and 3.38 grams and 7.3 and 17.6 grams as compared to 4.65 and 3.67 grams respectively, found in our study. Ahmad et al. (2008) and Khan and Begum (2005) reported 1000 seeds in Rainbow as 8.1 and 3.10 grams as compared to 4.6 grams in the present study. Malik et al. (2004) reported 1000-seed

weight ranged from 3.29 to 3.65 for canola cv. ZAFAR-2000, which was in the range of the present results. Cheema et al. (2001) reported 1000 seeds weight for Westar, Rainbow and Oscar as 3.42, 3.04 and 3.63 grams as compared to 4.80, 4.57 and 4.65 grams, respectively in the present study.

5.1.3.7 Seed Yield Grams Plant^{-1}

The seed yield per plant of different genotypes ranged from 20.75 (Westar) to 45.89 g in Peela Raya with a mean value of 39.93 g. Rahman et al. (2009) found seed yield/plant for Oscar and Altex as 4.05 and 3.68 grams/plant as compared to 22.03 and 26.84 grams/plant found in the present study, respectively. Swati (2005) reported seed yield as 17, 13.74, 5.89, 22 and 10.61 grams/plant for Raya Anmol, Oscar, Crusher, Torch and T-16-401 compared to 36.83, 22.03, 31.35, 29.04 and 24.61 grams/plant respectively, found in the present study.

5.1.3.8 Seed Yield (kg ha^{-1})

Yield kg ha^{-1} for different genotypes ranged from 1079 to 2386 kg ha^{-1} with mean value of 1732.5 kg ha^{-1}. Different authors have reported different yield for Brassica genotypes. Rahman et al. (2009) and Farhatullah et al. (2004) reported seed yield kg/ha^{-1} for Oscar and Altex as 825.3, 720.8 and 2500.0, 2388.9 as compared to 1146 kg/ha and 1396 kg/ha^{-1}, respectively in the present study. According to Malik et al. (2004) seed yield kg/ha^{-1} ranged from 2870 to 3725 kg/ha^{-1}. Shah et al. (2007) found in new hybrid Durr-e-NIFA, developed from an Australian canola genotype 'Dunkeld' and a local rapeseed mutant variety 'Abasin-95', yield 2630 kg/ha against the highest yield (1595 kg/ha) for *B. napus* genotype Legend, in the present study. The difference in yield could be due to the difference in the varieties/genotypes and ecological conditions. Our yield values for different genotypes are comparable to those of rapeseed genotypes used in advanced lines yield trail conducted at NIFA during 2000-01 (Shah et al. 2007). Anjum et al. (2005) reported seed yield kg/ha^{-1} for Westar, Rainbow, Oscar and Peela Raya as 1107, 1349, 1356 and 1279 as compared to 1079, 1399, 1146 and 2386, respectively in the present work. While Cheema et al. (2001) reported seed yield ha^{-1} for Westar,

Rainbow and Oscar as 1825, 1801 and 1843 kg/ha. Sarwar et al. (2004) reported Rainbow having yield performance (3330.0 Kg/ha) as compared to 1399 kg ha^{-1} in the present study.

5.1.3.9 Biological Yield (kg ha^{-1})

The biological yield kg ha^{-1} ranged from 12150 to 16270 kg ha^{-1} with a mean value of 14210 kg ha^{-1}. According to Malik et al. (2004) biological yield for Brassica genotypes ranged from 17460 to 24340 kg ha^{-1}. Cheema et al. (2001) reported biological yield ha^{-1} for Westar, Rainbow and Oscar as 13437, 11568 and 13333 kg as compared to 12540, 12380 and 13260 kg ha^{-1}, respectively, in the present study.

5.1.4 APHIDS DENSITY AND BIOCHEMICAL CONTENTS OF 12 BRASSICA GENOTYPES UNDER FIELD CONDITIONS

5.1.4.1 Oil Contents (%)

The result of the analysis of biochemical contents of all the 12 Brassica genotype revealed that the oil contents of the genotype ranged from 42.73% to 52.10% with a mean value of 47.42%. Abid et al. (2004) reported 47.3% and 45.7% oil contents in Rainbow and Oscar genotypes, respectively, which is similar to our results for canola type brassica. The present results are also in agreement to those of Rakow et al. (1995). According to them *B. napus* lines, 'cyclone', 'AC Elect' and 'Legacay' contained 46.1%, 47.2% and 46.6% oil, respectively. Swati (2005) reported oil content 46.02 for Oscar, 43.70 for Raya Anmol, 44.00 for Crusher, 43.40 for Torch and 44.20 for T-16-401 compared to 52.10, 47.65, 50.33, 50.43 and 42.73 respectively, in present study. According to Khan et al. (2008) oil content of different genotypes of Brassica ranged from 43 to 47% with a mean value of 45.4% which is a bit lower than our results. Mailer et al. (1998) also reported lower oil contents than ours, i.e. oil content of Australian canola crops ranged from 35% to over 45%.

5.1.4.2 Protein (%)

The protein content of all the 12 Brassica genotype ranged from 20.38 to 25.12% with a mean value of 22.75%. The present results are in agreement with the

findings of Abbas et al. (2008) and Velasco et al. (1999). They reported the protein values ranging from 22.3 to 27.52% and 13.4 to 28.3% in seed of Brassica genotypes, respectively. Khan et al. (2008) found protein contents in different genotypes of Brassica ranging from 23.0 to 25.6% with the mean value of 24.28%. Abid et al. (2004) reported range of values between 20.8 and 25.2% protein for genotypes Bulbul, Dunkled, Oscar, Rainbow, Range and Range (local) which are similar to the present findings.

5.1.4.3 Glucosinolate (μ mg^{-1}) Content

The glucosinolate contents of all the 12 genotype ranged from 67.35 to 132.7 μ mg^{-1} with a mean value of 100.02 μ mg^{-1}. Abbas et al. (2008) reported the glucosinolate values ranging from 57.89 to 119.80 μmol g-1 of seed with a mean value of 23.70μ mg^{-1} which was lower than our findings. According to Khan et al. (2008) the amount of glucosinolate contents ranged from 78 to 85 μ mg^{-1} with the over all mean value of 81.46 μmg^{-1} in different Brassica genotypes. Velasco et al. (1999) on the other hand reported a lower mean glucosinolate value of 51.2 μ mg^{-1} in fresh rapeseed using NIRS. Bhardwaj and Hamama (2000) reported much lower glucosinolate contents (49.2 μ mg^{-1}) in *Brassica napus.*

5.1.4.4 Moisture (%)

The moisture contents of all the 12 genotype ranged from 4.51 to 7.09 with a mean value of 5.8%. Khan et al. (2008) found moisture content between 6 to 7% with a mean value of 6.27% in different genotypes of Brassica, which is very close to results in the present study.

5.1.4.5 Oleic Acid (%)

The oleic acid content of the 12 genotype ranged from 29.93 to 54.74% with a mean value of 42.33%. Abid et al. (2004) reported 63.6% higher oleic acid for variety Rainbow than the value 52.48% recorded in the present findings. According to Khan et al. (2008) oleic acid (%) in different genotypes of Brassica ranged from 38 to 49% with mean value of 42.25%, that falls with in the range of present study. Pallot et al.

(1999) and Lavkopr et al. (2006) reported 56 to 74% oleic acid in brassica using NIRS. These values are much higher than the values in the present findings.

5.1.4.6 Linolenic Acid (%)

The linolenic acid content of the 12 varieties/genotype ranged from 7.65 to 12.86% with a mean value of 10.26%. Our results are in agreement with the findings of Khan et al. (2008). They reported linolenic acid content from 9 to 11% in different genotypes of Brassica. Lavkopr et al. (2006) observed 3.3 to 13.1% linolenic acid in brassica cultivars. The level of linolenic acid found by Pallot et al. (1999) was from 11.5-21.0% which was higher than our results.

5.1.4.7 Erucic Acid (%)

The erucic acid content of the 12 genotype ranged from 32.1 to 59.4% with a mean value of 45.75%. Abbas et al. (2008) reported 32.9 to 57.98% erucic acid content among the Brassica genotypes, but Khan et al. (2008) found slightly higher (48 to 59%) erucic acid content in different genotypes of Brassica.

5.2 LOSSES DUE TO *BRAVECORYNE BRASSICAE* IN DIFFERENT BRASSICA GENOTYPES UNDER SCREENHOUSE CONDITIONS

With artificial infestation of 5, 10 and 15 aphids/plant at flower-bud initiation stage in 12 Brassica genotypes, overall seed yield losses (%) ranged from 11.08% to 75.88% from an aphid's density /plant of 37.33 to 132.7, respectively.

Different workers have reported different levels of losses under different conditions in various genotypes of Brassica and species of aphids under different agro climatic conditions. Patel et al. (2004) observed that on an average there was 80.0 to 97.6 percent yield loss in *Brassica juncea* without plant protection. In our study we found losses range for *B. juncea* as 33.80 to 62.32 from aphids density/plant of 27.67 to 100.7 aphids/ plant. Kieckhefer and Gellner (1992) reported that yield losses caused by any of the aphid species in wheat were in the range of 35 to 40% at 15 aphids per plant. Munthali (2009) reported that Cabbage aphids caused 85% leaf damage on the most susceptible cultivar, Drumhead, and 30.9 and

44.6% on resistant cultivars, Grandslam and Copenhagen Market, respectively. Capinera (2008) observed that Cabbage aphid may cause 85% yield loss and may induce the increase in glucosinolate content in rape seed. Similarly Bakhetia (1984) observed 57.8 to 80.6 per cent yield loss due to mustard aphid. Brar et al. (1987) reported that the avoidable losses in yield of Brassica species caused by the mustard aphid varied from 28.8 to 52.5% in *B. juncea* cv. RLM 619 and 22.6 to 51.7% in *B. napus* cv. GSL 1. Suri et al. (1988) observed 42.1 per cent yield loss in brown sarson under different agro climatic conditions. Aheer et al. (1993) reported that on an average, 7.19 aphids per tiller on wheat reduced 16.38% yield. The damage caused by aphids in rape seed mustard vary from 9 to 95 percent depending upon various biotic and a biotic factors at different locations (Bakhetia and Aurora, 1993). Sachan and Purwar (2007) pointed out 29.5% and 2.6% grain yield losses in yellow sarson and Rai, respectively. Singh and Sachan (1994) reported the avoidable losses in yellow sarson due to mustard aphid *Lipaphis erysimi* up to 69.6 per cent. Roy and Baral (2002) reported that Mustard aphid alone attributes 30-70% losses in yield potential in different agro-climatic zones with a mean loss of 54.2% in India in rapeseed mustard. Population level increased beyond 9.45 aphids per plant; reduce the seed yield by 59.3 per cent with an economic injury level of 2.04 aphids/ plants with an index of 0.98 (Singh & Malik, 1989).

From the above findings it was concluded that to avoid losses from aphid population higher than 5 aphids/plant at flower-bud initiation stage should be avoided and control measures be carried out to avoid economic losses.

5.3 APHID'S DENSITY, YIELD AND YIELD COMPONENTS OF 12 BRASSICA GENOTYPES UNDER SCREENHOUSE CONDITIONS

The average aphid's density for all the Brassica genotypes in the study under screenhouse conditions ranged from 59.00 to 138.9 aphids per plant with a mean value of 98.95 aphids per plant.

5.3.1 Seed Yield Losses

With the range of aphids density per plant the average seed yield losses ranged from 1.79 to 4.33 with a mean of 3.06 grams/plant, while the average percent seed loss ranged from 23.18 to 57.87 with a mean value of 40.53%. Correlation among aphids and Seed yield percent loss was significant (0.52).

Liu et al. (1993) concluded that rape aphids influenced plant growth and yield losses. They reported that 500 aphids per 106 plants will cause 73.0% and 96.3% yield losses. Buntin and Raymer, (1994) reported that aphid reduced yield by 9.9 to 34.8% in the coastal plain region. Patil and Goud (2004) reported data on various aphids' densities and their effect on seed yield per plant in *Brassica juncea* L. at 25 days old crop infested with different loads of aphids, which accounts for 0.95, 14.23, 14.23, 21.27 and 26.42 losses from 20, 40, 60, 80 and 100 aphids, respectively. As compared to, the present study, average losses of 2.76, 3.81 and 5.57% in seeds yield per plant from infestation of 0, 5, 10 and 15 aphids at flower-bud initiation stage in the same species. Their data implies highly significant negative correlation value (-0.97) for aphids and seed yield losses/plant, in comparison to (-0.48) in present work.

Brown et al. (1999) found 37.3 and 15.6% seed yield reduction due to cabbage aphid, seedpod weevil and diamondback moth in *Brassica napus* L. and *B. juncea,* respectively. Bakhetia et al. (1987) reported 69% yield losses with 1:13 cost/benefit ratio from *Lipaphis erysimi* on *Brassica juncea* cv. RLM619 in field at Ludhiana. Bakhetia et al. (1987) reported Seed yield had negative correlation with mean and cumulative aphid population. Increase of one aphid decreased seed yield by 4.98 kg/ha. Razaq et al. (2011) reported 45.38, 48.06 and 48.27% losses in seeds/siliqua in *B. napus*, *B. juncea* and *B. carinata* from aphid's density of 70, 78.33 and 65.66 /plant, respectively against our values of 43.24, 44.77 and 50.04% losses in seeds yield/plant with aphid's density of 101.16, 62.00 and 65.72 /plant. Saljoqi et al. (2009) found relationship between the number of aphids and yield in canola crop. They reported that with the increase of aphid population the yield decreased and that an aphid's infestations of 216.10 cause a yield loss of 605kgha^{-1}.

They found strong negative relationship between the mean number of aphids and yield in canola crop. Capinera (2008) reported that Cabbage aphids cause 85% yield loss in rape seed. This figure is much higher than our highest loss value (57.87%).

5.3.2 Straw Yield Losses

With average aphid's density ranging from 59.00 to 139.9 and mean value 98.95 aphids per plant, the average straw yield loss ranged from 12.56 to 19.62 with a mean value of 16.09 g/plant. While the average percent straw yield loss ranged from 23.18 to 57.87 with a mean value of 40.53%. Correlation among aphids and Straw yield percent loss was 0.41.

5.3.3 Plant Height Losses

With average aphid's density ranging from 59.00 to 139.9 and mean value 98.95 aphids per plant average plant height ranged from 82.1 to 153.4 with mean value of 117.75 cm/plant. Average percent height % loss ranged from 25.32 to 38.78 with mean value of 32.05%. Correlation among aphids and Plant Height percent loss was highly significant (0.75)

Patil and Goud (2004) reported data on various aphids' densities on plant height losses in variety *Brassica juncea* L. at 25 days old crop infested with different loads of aphids, which accounts for 2.12, 2.62, 3.05, 4.48 and 5.50% losses in plant height from 20, 40, 60, 80 and 100 aphids, respectively. As compared average losses of 16.19, 32.38 and 48.57% losses in Plant height were incured with infestation of 5, 10 and 15 aphids at flower-bud initiation stage in the same species. Their data implies highly significant negative correlation value (-0.97) for aphids and plant height losses. Razaq et al. (2011) reported 15.69, 12.51 and 31.13% plant height losses in *B. napus*, *B. juncea* and *B. carinata* from aphid's density of 70, 78.33 and 65.66 /plant, respectively. The values of the present findings are 34.28, 32.38 and 25.32% plant height losses with aphid's density of 101.16, 62.00 and 65.72 /plant, showing similar pattern. Capinera (2008), reported that Cabbage aphid reduce 35% plant growth in rape seed. This value lies with in the range of findings of this study. Liu et al. (1993) reported that 5000-7000 aphids per 106 plants cause

41.6% and 50.4% loss in plant height. Khan and Begum (2005) found plant height 118.5 cm in Rainbow with 3.13 aphids/ leaf as compared to 97.47 cm with 138.9 aphids/ plant in present study. Buntin and Raymer, (1994) reported that aphid injury reduced plant height and delayed plant development.

5.3.4 Branches Losses

With average aphid's density ranging from 59.00 to 139.9 and mean value 98.95 aphids per plant, the average Branches plant^{-1} loss ranged from 5.39 to 12.05 with a mean value of 8.73 branches/plant. Average percent Branches loss ranged from 6.25 to 27.78 with a mean value of 17.02%. Correlation among aphids and Branches percent loss was highly significant (0.59).

Liu et al. (1993) reported that 5000-7000 aphids per 106 plants decreased the number of plant branch by 51.1% and 76.3%. Patil and Goud (2004) reported data on various aphids' densities and their effect on Branches losses in *Brassica juncea* L. at 25 days old crop infested with different loads of aphids, which accounts for 19.67, 24.04, 28.34, 34.85 and 45.73% losses from 20, 40, 60, 80 and 100 aphids, respectively. Results of the present findings show average of 7.69, 9.62, 13.46% losses in number of branches from infestation of 5, 10 and 15 aphids at bud initiation stage in the same species. Their data implies highly significant negative correlation value (-0.96) for aphids and branches number losses. Capinera (2008) reported that Cabbage aphid reduce 43% side branches in rape seed. Brown et al. (1999) found 1.3 and 1.2% reduction in number of branches due to cabbage aphid, seedpod weevil and diamondback moth in *Brassica napus* L. and *B. juncea,* respectively.

5.3.5 Siliqua main raceme^{-1} Losses

With average aphid's density ranging from 59.00 to 138.9 and mean value 98.95 aphids per plant the average number of siliqua main raceme^{-1} loss due to aphids ranged from 8.61 to 32.67 with a mean value of 20.64 siliquae mr^{-1}. Average percent loss in the number of siliquae mr^{-1} due to aphids ranged from 16.24 to 40.20 with a mean value of 28.22%. Correlation among aphids and siliqua mr^{-1} percent loss was non significant (0.47).

Bakhetia et al. (1987) reported .06% decrease in siliqua/main shoot from *Lipaphis erysimi* on *Brassica juncea* cv. RLM-619 in field at Ludhiana . Patil and Goud (2004) reported data on various aphids' densities and their effect on siliqua per plant losses in *Brassica juncea* L. at 25 days old crop infested with different loads of aphids. This accounts for 3.77, 5.39, 7.54, 12.60 and 13.68% losses from 20, 40, 60, 80 and 100 aphids, respectively. Results of the present study show average losses of 6.32, 12.63 and 45.79% in siliquae per main raceme from infestation of 5, 10 and 15 aphids at bud initiation stage in the same species. Their data implies highly significant negative correlation value (-0.99) for aphids and branches number losses. Razaq et al. (2011) reported losses of 56.84, 64.14 and 78.68% siliquae/plant in *B. napus*, *B. juncea* and *B. carinata* from aphids density of 70, 78.33 and 65.66 /plant, respectively, against our values of 26.97, 21.58 and 38.49 with aphids density of 101.16, 62.00 and 65.72 /plant, showing similar pattern. Brown et al. (1999) found 47.5 and 4.5% reduction in number of siliquae on main raceme due to cabbage aphid, seedpod weevil and diamondback moth in *Brassica napus* L. and *B. juncea,* respectively.

5.3.6 Leaves Losses

With average aphid's density ranging from 59.00 to 138.9 and mean value 98.95 aphids per plant the average leaves loss/plant due to aphids ranged from 21.83 to 38.28 with a mean value of 30.06 leaves/plant. Average percent leaves loss/plant due to aphids ranged from 7.21 to 27.63 with a mean value of 17.42%. Correlation among aphids and Branches percent loss was non significant (0.32).

Buntin and Raymer, (1994) reported *Myzus persicae* (Sulzer) causing direct injury to leaves but exact damage is not mentioned. Liu et al. (1993) reported that 5000-7000 aphids per 106 plants decreased the leaf area by 69.5% and 71.3%. Rassoulian, (1989) indicated that the green pea aphid decreased the foliage yield of alfalfa between 27.7-75.5% and spotted alfalfa aphid decreased the foliage yield between 20-51%.

5.4 APHID'S DENSITY AND BIOCHEMICAL CHARACTERISTICS OF 12 BRASSICA GENOTYPES UNDER SCREENHOUSE CONDITIONS

Among all the Brassica genotypes average aphids population ranged from 59.00 to 138.9 with a mean value of 98.95 aphids per plant.

5.4.1 Oil Contents

With the above average aphid's density per plant the oil contents in the respective genotypes ranged from 37.27 to 47.93% with a mean value of 42.60% against 38.72-47.98 % and 43.35 % in the control with 0.10 to 6.13 percent losses.

Capinera (2008) observed that Cabbage aphid may reduce oil content by over 10% in rape seed. Kelm and Gadomski (1995) reported that aphid infestation caused seed yield loss ranged from 9-77%. Aphid also caused an 11% reduction in seed oil content. Brown et al. (1999) found 7.6 and 5.2% oil content reduction due to cabbage aphid, seedpod weevil and diamondback moth in *Brassica napus* L. and *B. juncea,* respectively. Rahman et al*.* (2009) reported 44.82 µmol/g glucosinolate, 23.67 erucic acid and 59.01% oleic acid in Siren. Haq et al (2009) analyzed different Genotypes of canola oil seed of *Brassica napus* and *Brassica rapa* and found oil in the range of 40.38-45.56%. Khan et al (1998) reported percentage of oil contents (46.23%) in the in *Brassica napus* L. variety 2013. Anwar et al. (2009) reported oil contents from canola seeds ranged from 34.3 to 39.3% from the seeds of five locally grown canola cultivars: Zafar (2002), Bulbul (Frontier), Dunkeld, Oscar and Con-II. Cheema et al. (2001) reported seed oil contents from 41.76 to 39.94% in brassica. Aytac and Kinaci (2009) reported oil content ranging from 37.03 to 41.92% with a mean value of 39.57% in various winter rapeseed genotypes. Abid et al*.* (2004) reported 47.3% and 45.7% oil contents in Rainbow and Oscar Genotypes, compared to 44.67 and 44.60 in the present study, respectively. Swati (2005) reported oil content 46.02 for Oscar, 43.70 for Raya Anmol, 44.00 for Crusher, 43.40 for Torch and 44.20 for T-16-401 compared to 44.60, 40.20, 44.53, 47.98 and 38.27%, respectively, in the uninfested control treatment in the present study. According to Khan et al*.* (2008) oil content of different genotypes of Brassica ranged from 43 to

47% with a mean value of 45.4% which is similar to our results. Mailer et al. (1998) also reported similar oil contents as ours, i.e. oil content of Australian canola crops ranged from 35% to over 45%. Tahir et al. (2007) found seed oil content 44.38. They reported that oil contents of the seed were not affected significantly by varying irrigation levels. In another experiment under field conditions the oil contents of the same genotypes ranged from 42.73 to 52.10% with a mean value of 47.42%. This shows that oil contents decrease due to aphids and other environmental stresses.

5.4.2 Protein Contents

With corresponding aphid's density in 12 different genotypes protein contents ranged from 24.70 to 29.83 with a mean value of 27.27%. The protein content in untreated control ranged from 22.45 to 27.98 with a mean value of 25.22 with percent increase of 4.04 to 24.57 with mean value of 13.22.

This shows that protein contents have increased due to some other morphological, physiological and environmental factors. Haq et al (2009) analyzed different genotypes of canola oil seed of *Brassica napus* and *Brassica rapa* and found protein in the range of 21.43-27.01%. Anwar et al. (2009) reported levels of protein from canola seeds ranging from 22.1-41.0% from the seeds of five locally grown canola cultivars: Zafar-2002, Bulbul (Frontier), Dunkeld, Oscar and Con-II. Aytac and Kinaci (2009) reported protein content ranging from 18.27 to 20.17% with a mean value of 19.11% in various winter rapeseed genotypes.

The protein content of the 12 Brassica genotypes ranged from 24.70 to 29.07% with a mean value of 26.89%, showing some increase in present study, meaning that aphids and some environmental factors have caused increase in the protein%. Similar slightly less values have also been reported by Abbas et al. (2008) and Velasco et al. (1999). They reported the protein values ranging from 22.3 to 27.52% and 13.4 to 28.3% in seed of Brassica genotypes, respectively.

Rassoulian (1989) indicated that spotted alfalfa aphid decreased the protein contents 25-50%. Khan et al. (2008) found protein contents in different genotypes of Brassica ranging from 23.0 to 25.6% with the mean value of 24.28%. Abid et al.

(2004) reported range of values between 20.8 and 25.2% protein for Genotypes Bulbul, Dunkled, Oscar, Rainbow, Range and Range (local) which are all slightly less than in the present findings. Tahir et al. (2007) found seed protein content 20.52. The protein contents of the seed were not affected significantly by varying irrigation levels.

5.4.3 Glucosinolates (μ mg^{-1}) Content

With corresponding aphids density the glucosinolates content of the 12 genotype ranged from 61.9 to 167.0 μ mg^{-1} with a mean value of 114.45 μ mg^{-1}. The glucosinolates (μ mg^{-1}) content in the uninfested control ranged from 71.17 to 180.90 with a mean value of 126.04 with 7.67 to 15.00 percent losses and 3.99-37.07 gain. The correlation among aphids and glucosinolates was non-significant (0.440).

Capinera (2008) observed that Cabbage aphid may induce the increase in glucosinolate content in rape seed. Cole (1997) reported significant differences in glucosinolates concentrations and significant correlation (r=0.83) between the rate of increase of *Brevicoryne brassicae* and glucosinolate in dried leaves in wild *Brassica* species. He found correlation between amino acid and the rate of increase of *B. brassicae* (r=0.48). Haq et al. (2009) analyzed different Genotypes of canola oil seed of *Brassica napus* and *Brassica rapa* and found glucosinolate contents in the range of and 21.43-50.63mumol/g. Yusuf and Collins (1998) suggested that aphids were attracted in greatest numbers to leaves that had the highest synthesis of glucosinolates and that their presence resulted in reduced glucosinolate levels. Anwar et al. (2009) reported that glucosinolate (GSL) contents in the canola seeds ranged from 49.7 to 78.1 μ mol/g from the seeds of five locally grown canola cultivars: Zafar-2002, Bulbul (Frontier), Dunkeld, Oscar and Con-II. Khan et al. (1998) found lower quantities of glucosinolates (80.25 micro mole gm^{-1}) in the *Brassica napus* L. Variety 2013. Cheema et al. (2001) reported glucosinolates ranging from 13.68 to 39.39% in Brassica genotypes similar to our studies. Lammerink et al. (1984) reported total glucosinolate level for 2 sowing dates were 32 and 46 μ mole/g in seed from severely infested rape compared with 27 and 21 μ

mole/g in seed from rape having fewer aphids. Lammerink et al. (1984) reported that seed meal from rape heavily infested with cabbage aphid have increased level of glucosinolates. Lammerink et al. (1984) reported that in the glasshouse trials, seed from plants with aphids contained 24 µ mole glucosinolate/g, whereas seed from plants infested with aphids for 10 days at pre to early flowering, at full to late flower, or at post flowering, contained 43, 40 and 32 µ mole glucosinolate/g. Abbas et al. (2008) reported the glucosinolates value ranging from 57.89 to 119.80 µmol g^{-1} of seed with a mean value of 23.70µ mg^{-1} which was lower than our findings. According to Khan et al. (2008) the amount of glucosinolate content ranged from 78 to 85µmg^{-1} with the over all mean value of 81.46µmg-1 in different Brassica genotypes. Velasco et al. (1999) on the other hand reported a lower mean glucosinolate value of 51.2µ mg^{-1} in fresh rapeseed using NIRS. Bhardwaj and Hamama (2000) reported much lower glucosinolates content (49.2 µ mg^{-1}) in *Brassica napus.* Rahman et al. (2009) reported 44.82 µmol/g glucosinolate in genotype Siren. Kumar et al. (2010) suggested that total glucosinolates in seeds were positively correlated (r=0.814) and hence could be a good criterion for identifying low glucosinolates lines at early stage.

5.4.4 Moisture (%)

With relative aphids density in the seeds of 12 different genotypes the moisture contents ranged from 2.83 to 6.43 with mean value of 4.63%. The moisture contents in the uninfested control ranged from 3.20 to 6.97 with a mean value of 5.08 with average percent loss (Table-4.14) ranged from 1.03 to 21.27 and gain from 0.87 to 5.53.

Anwar et al. (2009 reported levels of moisture from canola seeds ranged from 4.0-7.5% from the seeds of five locally grown canola cultivars: Zafar-2002, Bulbul (Frontier), Dunkeld, Oscar and Con-II. Haq et al (2009) analyzed different genotypes of canola oil seed of *Brassica napus* and *Brassica rapa* and found average moisture, were in the range of 5.92-6.58%.

The moisture contents of the 12 genotype ranged from 4.51 to 7.09 with a mean value of 5.8%. Khan et al. (2008) found moisture content between 6 to 7%

with a mean 6.27% in different genotypes of Brassica, which is very close to results in the present study.

5.4.5 Oleic Acid (%)

With respective aphids density in the seeds of 12 different genotypes the oleic acid % ranged from 33.7 to 67.07 with a mean value of 50.39%. The oleic acid (%) in the uninfested control ranged from 31.77 to 68.03 with a mean value of 49.90 with average percent loss ranged from 1.42 to 8.25 and gain from 0.33-19.82.

Anwar et al. (2009 reported seed oils of the five canola cultivars mainly consisted of oleic acid (C18:1) at levels of 49.16-62.14% from the seeds of five locally grown canola cultivars: Zafar-2002, Bulbul (Frontier), Dunkeld, Oscar and Con-II. Rahman et al. (2009) reported 59.01% oleic acid in genotype Siren.

The oleic acid content of the 12 genotype ranged from 29.93 to 54.74% with a mean value of 42.33%. Abid et al. (2004) reported 63.6% higher oleic acid for variety Rainbow than the value 52.48% recorded in the present findings. According to Khan et al. (2008) oleic acid (%) in different genotypes of Brassica ranged from 38 to 49% with mean value of 42.25%, that falls with in the range of present study. Pallot et al. (1999) and Lavkopr et al. (2006) reported 56 to 74% oleic acid in Brassica using NIRS. This value is much higher than the present.

5.4.6 Linolenic Acid (%)

With corresponding aphids density in 12 different genotypes the Linolenic Acid contents ranged from 8.13 to 12.37 with a mean value 10.25%. The linolenic acid content in the untreated control ranged from 7.77 to 12.43 with a mean value of average loss (Table-4.14) ranged from 0.46 -8.55 and gain from 1.11-13.93.

Anwar et al. (2009) reported seed oils of the five canola cultivars mainly consisted of linolenic acid (C18:2) at levels of 14.61 to 23.45% from the seeds of five locally grown canola cultivars: Zafar-2002, Bulbul (Frontier), Dunkeld, Oscar and Con-II.

The linolenic acid content of the 12 varieties/genotype ranged from 7.65 to 12.86% with a mean value of 10.26%. Our results are in agreement with the findings of Khan et al. (2008). They reported linolenic acid content from 9 to 11% in different genotypes of brassica. Lavkopr et al. (2006) observed 3.3 to 13.1% linolenic acid in Brassica cultivars. The level of linolenic acid found by Pallot et al. (1999) was from 11.5-21.0% which was higher than our results.

5.4.7 Erucic Acid (%)

With corresponding aphid's density in 12 different genotypes the erucic acid in the seeds ranged from 22.00 to 55.83 with a mean value of 38.92%. The erucic acid (%) in the uninfested control ranged from 19.40 to 56.90 with mean value of 38.15 with average loss (Table-4.14) ranged from 0.76 to 9.20 and gain from 11.08 to 31.38.

Anwar et al. (2009 reported seed oils of the five canola cultivars mainly consisted of erucic acid ranged from 3.47 to 6.00% from the seeds of five locally grown canola cultivars: Zafar-2002, Bulbul (Frontier), Dunkeld, Oscar and Con-II. Haq et al (2009) analyzed different genotypes of canola oil seed of *Brassica napus* and *Brassica rapa* and found the maximum erucic acid level in V2 i.e. 3.73%, while the V11 (Altex) contained the lowest erucic acid i.e. 0.25%. Cheema et al. (2001) reported seed erucic acid 3.46 to 16.05% in Brassica genotypes similar to our studies. Rahman et al. (2009) reported 23.67 erucic acid contents in genotype Siren. Leto et al. (1996) reported that in the more productive year the average erucic acid content markedly decreased.

The erucic acid content of the 12 genotypes ranged from 32.1 to 59.4% with a mean value of 45.75%. Abbas et al. (2008) reported 32.9 to 57.98% erucic acid content among the Brassica genotypes, but Khan et al. (2008) found slightly higher (48 to 59%) erucic acid content in different genotypes of Brassica.

CHAPTER-VI

SUMMARY

Screening of brassica genotypes against aphids was carried out during 2006-07 and 2007-08 on the Research Farm of Khyber Paktunkhwa Agricultural University Peshawar. Twelve brassica genotypes i.e. Westar, Ganyou-5, Rainbow, Oscar, Vangard, Crusher, Torch, Legend, Altex, Raya Anmol, Peela Raya and T-16-401 representing four Brassica species including *B. napus*, *B. juncea*, *B. carinata* and *B. campestris* were tested for aphid's density and yield; losses and relationship between aphids populations and morphological and quality characteristics.

Data on aphid's density showed that average aphid's density per plant on 12 Brassica genotypes during 2006-07 and 2007-08 was at peak during the 2nd and 3rd weak February. The highest aphids density was recorded on Legend (37.94 aphids/plant) followed by Ganyou-5 (34.87 aphids/plant), Oscar (30.47 aphids/plant), Raya Anmol (27.57 aphids/plant), Rainbow (26.86 aphids/plant), Torch (25.39 aphids/plant), T-16-401 (24.89 aphids/plant), Peela Raya (23.55 aphids/plant), Westar (23.41 aphids/plant), Altex (21.57 aphids/plant), Crusher (18.42 aphids/plant) and lowest on Vangard (12.84 aphids/plant). Statistically there were significant differences in the number of aphids/plant among the genotypes. No genotype was found completely free from aphids, however, based on aphids population different genotypes can be characterized as tolerant or susceptible. Vangard with minimum aphids /plant was the most tolerant followed by Crusher, Altex, Westar, Peela Raya, T-16-401, Torch, Rainbow, Raya Anmol, Oscar, Ganyou-5 and Legend as most susceptible, in the order.

Seed yield kg ha^{-1} was highest (2386 kg/ha) in Peela Raya and lowest in Westar (1079 kgha^{-1}), respectively. Biological yield (kg ha^{-1}) was highest in Peela Raya (16270 kgha^{-1}), lowest in Ganyou-5 (12150kg/ha), plant height was highest in Peela Raya (214.3 cm) and lowest in Westar (150.4 cm); Primary branches were highest for Peela Raya (19.20) and lowest in Westar 6.94; siliquae main raceme^{-1} were highest for Vangard (70.20), lowest in Peela Raya 20.76, siliquae length longest in Ganyou-5 (8.31) and shortest in Altex (4.02); seeds per siliqua were highest in Oscar (23.57 seeds) and lowest in Legend (9.38 seeds), 1000 seeds weight was highest in Westar

(4.80 g) and lowest in T-16-401 (3.37g); seed yield grams plant^{-1} was highest in Peela Raya (45.89) and lowest in Westar (20.75grams). For *B. napus* group highest seed yield kg ha^{-1} was recorded in genotype Crusher (1630 kgha^{-1}).

Based on biochemical analysis oil contents were highest in Oscar (52.10%), and lowest in T-16-401 (42.73), protein contents was highest (25.12%) in T-16-401, and lowest in Vangard (20.38), glucosinolate contents were highest (132.7 µ mg^{-1}) in T-16-401, lowest in Rainbow (67.35 µ mg^{-1} moisture content was highest in Oscar (7.09%) and lowest in Peela Raya (4.51%), oleic acid content was highest in Westar (54.74%) lowest in Peela Raya (29.93%), linolenic contents were highest in Raya Anmol (12.86) and lowest in Westar (7.65%), erucic acid content were highest in Raya Anmol (56.2%) and lowest in Crusher (36.44%).

To determine the effects of aphid's density on yield losses in different Brassica genotypes twelve genotypes were grown in the screenhouse in plastic pots at the rate of two plants per pot, at the Institute of Biotechnology and Genetic Engineering (IBGE), Agricultural University Peshawar during 2006-07 and 2007-08. At flower-bud initiation stage each plant of a genotype in the pot was infested @ 5, 10 and 15 aphids/plant. Aphid's population and its effects on yield losses were determined. The results showed that that among all the Brassica genotypes infested with 5-aphids per plant at flower-bud initiation stage seed yield losses (%) were highest for Torch (44.50%) with aphid's density/plant (59.33). Lowest yield losses (11.09%) were recorded in genotype T-16-401 with aphid's density of 37.33 aphid/ plant, among the tested genotypes. Among the *Brassica napus* group Legend had the lowest yield losses of 16.22% with aphid's density of 69.67 per plant. Statistically there was significant difference among the yield losses of tested genotypes from different aphid's densities. Among all the Brassica genotypes infested with 10-aphids per plant at flower-bud initiation stage the highest yield losses (62.20%) were recorded in genotype Vangard with aphid density/plant of 97.00. Lowest yield losses (22.16%) were recorded in genotype T-16-401 with aphid's density/plant of 54.50. Among the *Brassica napus* group Legend had the lowest yield losses of 23.62% with aphid's density/plant of 125.7 aphids/plant. Among all the Brassica genotypes infested with 15-aphids per plant at flower-bud initiation stage the

highest yield percent losses of 75.89% occurred in Vangard from 132.7 aphids/plant. The lowest yield losses (29.16%) were recorded in the genotype T-16-401 from 85.17 aphids/plant. Among the *Brassica napus* group the lowest yield losses (44.01%) were reported in Rainbow from 200.7 aphids/plant. Statistical analysis of the data showed that there was no significant difference among losses in Peela Raya (68.38%) and Vangard (75.89%). These were the highest yield losses in the tested genotypes. The losses in Rainbow, Westar and Ganyou-5 were non-significantly different.

Among all the Brassica genotypes grown under screenhouse conditions and infested with 0, 5, 10 and 15 aphids/plant at flower-bud initiation stage, highest average aphids density was observed in the genotype Rainbow (138.9), and lowest in T-16-401 (59.0) aphids per plant. Highest average percent seed loss was recorded in Vangard (57.87) and lowest in T-16-401 (23.18%). Correlation among aphids and seed yield percent loss was significant (0.52). The highest average percent straw loss was recorded in Peela Raya (46.35) and lowest in Ganyou-5 (20.35). Correlation among aphids and Straw yield percent loss was non-significant (0.41). Average highest percent loss in plant height was recorded in the genotype Westar (38.78), and lowest in Peela Raya (25.32). Correlation among aphids and Plant Height percent loss was highly significant (0.75). The average highest percent Branches loss was recorded in the genotype Crusher (27.78), and lowest in T-16-401 (6.25). Correlation among aphids and Branches percent loss was highly significant (0.59). Average highest percent loss in the number of siliquae on main raceme due to aphids was the highest in Oscar (40.20) and lowest in Westar (16.24). Correlation among aphids and siliqua mr^{-1} was non-significant (0.47). Average highest percent leaves loss/plant due to aphids was recorded in the genotype Legend (27.63) and the lowest in Westar (7.21). Correlation among aphids and Leaves loss/plant was non-significant (0.32).

Among all the Brassica genotypes under screenhouse conditions infested with 0, 5, 10 and 15 aphids/plant at flower-bud initiation stage aphid's population ranged from 59.0 aphids in T-16-401 to 138.9 in Rainbow. Highest oil contents were recorded in the genotype Torch (47.93) and lowest in T-16-401 (37.27). Correlation among aphids and Oil contents was -0.195. Highest average oil% losses were recorded in Crusher (6.13)

and lowest in Torch (0.10). Protein contents were highest in the genotype Oscar (29.83) and lowest in Ganyou-5 (24.70). Correlation among aphids and protein contents was -0.001. Highest protein% increase was recorded in Oscar (24.57) and lowest in Raya Anmol (4.04). Highest glucosinolate contents were recorded in the genotype T-16-401 (167.0) and lowest in Legend (61.90). Correlation among aphids and glucosinolates in the seeds was non-significant negative (-0.204). Highest percent gain in glucosinolate was recorded in the seed of Rainbow (37.07) and lowest in Altex (3.99) and highest loss in Legend (15.00) and lowest in T-16-401 (7.67). Highest moisture contents were recorded in the seeds of Brassica genotype Oscar (6.43) and lowest in Peela Raya (2.83). Correlation among aphids and moisture contents was 0.397. Highest percent loss in moisture percentage due to aphids was recorded in the seed of T-16-401 (21.27) and lowest in Oscar (1.03) and highest percent gain in Rainbow (5.53) and lowest in Crusher (0.87). Highest oleic acid contents was found in Ganyou-5 (67.07) and lowest in Peela Raya (33.70). Correlation among aphids and oleic acid contents in the seeds was 0.209. Highest percent losses in oleic acid contents due to aphids, recorded in the seed of Brassica were in Rainbow (8.25) and lowest in Gainyou-5 (1.42) and highest percent gain in T-16-401 (19.82) and lowest in Raya Anmol (0.33). Highest Linolenic Acid was found in Peela Raya (12.37) and lowest in Vangard (8.13). Correlation among aphids and linolenic acid in the seeds Brassica was -0.334. Highest percentage losses in linolenic acid due to aphids, recorded in the seed of Brassica, were in Raya Anmol (8.55) and lowest in Crusher (0.46) and highest gain in Westar (13.93) and lowest in T-16-401 (1.11). Erucic acid was highest in the seeds of genotype Torch (55.83) and lowest in Ganyou-5 (22.00). Correlation among aphids and erucic acid in the seeds was 0.052. Highest percent losses in erucic acid due to aphids, recorded in the seed of Brassica were in T-16 (9.20) and lowest in Vangard (0.76) and highest percent gain in Legend (31.38) and lowest in Westar (11.08).

CONCLUSION AND RECOMMENDATIONS

Among all the tested brassica species none of the genotype was found completely resistant. Different aphid's population caused different losses in different genotypes. A number of factors are responsible for increase of aphid's population that can not be taken care of in each study. Under field conditions, amongst the nine *B. napus* genotypes Crusher and Vangard had the lowest aphid's density /plant and highest seed yield and relatively higher oil, protein contents and lower glucosinolates. Under artificial infestation at flower-bud initiation stage all the genotypes showed very high percent losses due to aphids. This shows that under natural field conditions there is some mechanism (s) that helps to keep aphids population low. This study will help/provide information to a number of clients including farmers, agri-business people, breeders, veterinary scientists and workers. Farmers will be able to decide the best genotype to consider for cultivation based on aphids attack, yield, plant characteristics and biochemical characteristics. Breeders will have information on different morphological and chemical characteristics of the plant with respect to aphid infestation. Veterinarian will be able to select best genotype based on their chemical composition – oil quantity, protein contents, glucosinolates, and amino acids. Agri-business people will be able to select the best genotype based on oil contents, protein contents, and glucosinolates and amino acids contents.

- Based on tolerance against aphids, recovery of oil contents, comparatively better protein contents and glucosinolates, genotypes Crusher and Vangard can both be used for general cultivation and for possible resistance against aphids as potential source for breeding programs.
- Similarly Raya Anmol and Peela Raya exhibited superiority in yield potential and therefore can be considered by breeding programs meant to increase the production.
- Biochemical analyses confirmed previous results and as such are recommended as a reliable tool for screening methods for their oil contents and oil quality.

CHAPTER-VII

LITERATURE CITED

Abbas, S.J., Farhatullah, I. A. Khan, K.B. Marwat, and I. Munir. 2008. Molecular and biochemical assessment of *Brassica napus* and indigenous *Campestris* species. Pak. J. Bot. 40(6): 2461-2469.

Abid, H.K., A.K. Iqtidar and H. Shah. 2004. Nutritional yield and oil quality of canola cultivars grown in NWFP. Sarhad J. Agric. 2(2): 287-290.

Agarwala, B.K. and N. Datta. 1999. Life history response of the mustard aphid *Lipaphis erysimi* to phonological changes in its host. J. Biosciences. 24(2): 223-231.

Agnihotri, A. and N. Kaushik. 1999. Genetic enhancement for double low characteristics in India rapeseed mustard. In Proceedings of the X International Rapeseed Congress. Canberra, Australia. pp. 26-29.

Aheer, G.M., A. Rashid, M. Afzal and A. Ali. 1993. Varietal resistance/susceptibility of wheat to aphids, *Sitobion avenae* F. and *Rhopalosiphum rufiababdminalis* Sasaki. J. Agric. Res. 31(3): 307-311.

Ahmad, H., M. Islam, I.A. Khan, H. Ali, H. Rahman and Inamullah. 2008. Evaluation of advance rapeseed line HS-98 for yield attributes and biochemical characters. Pak. J. Bot. 40(3): 1099-1101.

Akbar, M., T. Mahmood, M. Yaqub, M. Anwar, M. Ali, and N. Iqbal. 2003. Variability, correlation and path coefficient studies in summer mustard (*Brassica juncea* L.), Asian J. Plant Sci. 2(9): 696-698.

Akbar, M., U.T. Saleem, M. Yaqub and N. Iqbal. 2007. Utilization of genetic variability, correlation and path analysis for seed yield improvement in mustard, *Brassica juncea* L. J. Agric. Res. 45(1): 25-31.

Ali, N., F. Javidfar, J.Y. Elmira and M.Y. Mirza. 2003. Relationship among yield components and selection criteria for yield improvement in winter rapeseed (*Brassica napus* L.). Pak. J. Bot. 35(2): 167-174.

Al-Barzinjy, M., O. Stolen, and J. L. Christiansen. 2003. Comparison of growth, pod distribution, and canopy structure of old and new cultivars of oilseed rape (*Brassica napus* L.) Acta Agric. Scand. Sect. (B) Plant Soil Sci. 53(3): 138-146.

Amjad, M., N. Islam and S. A. Kakakhel. 1999. Turnip Aphid *Lipaphis erysimi* Kalt. (Homoptera: Aphididae) Biology, Intrinsic Rate of Increase and Development Threshold Temperature on Oilseed Brassica. Pak. J. of Biol. Sci. 2(3): 599-602.

Amjad, F. 2007. Insect pests of Canola (*Brassica Spp*.) and their management. Institute of Pure & Applied Biology. Bahauddin Zakariya University Multan. pp.209.

Anjum, R., M. Yousaf, M. Jahangir, M. Hussain, N. Nawaz and A. Ahmed. 2005. Adaptation and yield potential of different genotypes of rapeseed and mustard under agro-climatic conditions of Bahawalpur (Pakistan). Int. J. Agric. Biol. 7(4): 609–611.

Anwar, M., M. Shafique. 1999. Relative development of aphids on different Brassica cultivars. Pak. J. Zool. 31(4): 357-359.

Amer, M., M. Aslam, M. Razaq and M. Afzal. 2009. Lack of plant resistance against aphids, as indicated by their seasonal abundance in canola, (*Brassica napus* l.) in southern Punjab, Pakistan. Pak. J. Bot. 41(3): 1043-1051.

Aslam, M., M. Razaq and A. Shahzad. 2005. Comparison of different canola (*Brassica napus* L.) varieties for Resistance against cabbage aphid (*Brevicoryne brassicae* L.) Int. J. Agri. Biol. 7(5): 781-782.

Aytac, Z., G. Kinaci and E. Kinaci. 2008. Genetic variation, heritability and path analysis of summer rapeseed cultivars, J. Appl. Biol. Sci. 2(3):35-39.

Aytac, Z. and G. Kınacı. 2009. Genetic variability and association studies of some quantitative characters in winter rapeseed (*Brassica napus* L.). Afr. J. Biotechnol. 8 (15): 3547-3554.

Bakhetia, D.R.C. 1984. Chemical control of *Lipaphis erysimi* (Kaltenbach) on rapeseed and mustard crop in Punjab. J. of Res. Punjab Agric. Uni. 21: 63-75.

Bakhetia, D.R.C. and A.W. Ghorbandi, 1987. Assessment of yield losses and determination of economic injury levels for *Lipaphis erysimi* (Kaltenbach) on Indian mustard: - based on aphid population [India]. 11. International Congress of Plant Protection, Manila (Philippines), Oct 5-9, 1987. http://www.uplb.edu.ph/

Bakhetia, D.R.C. and R. Arora. 1993. Changing Scenario of Insect Pest Management in rapeseed mustard. In Pest and Pest Management in India - the changing Scenario. (Ed. H.C. Sharma and M.V. Rao). Lead paper of the national seminar on Change Scenario in Pest and Pest Management in India. 31-Jan.-1-Feb., 1992. Plant Protection Association of India, Hyderabad, pp 56-69.

Bakhetia, D.R.C. and O.S. Bindra.1977. Screening technique for aphid resistance in *Brassica* crops. SABRAO Jour. 9(2) 91-107.

Bhatia V, Uniyal P. L, Bhattacharya R. 2011. Aphid resistance in Brassica crops: challenges, biotechnological progress and emerging possibilities. Biotechnol Adv. 29(6):879-88.

Brar, K.S., D.R.C. Bakhetia and B.S. Sekhon. 1987. Estimation of losses in yield of rapeseed and mustard due to mustard aphid**.** J. Oilseeds Res. (India). 4(2): 261-264.

Beck, S.D. 1965. Resistance of plants to Insects. Ann. Rev. Entomol. 10: 207-232.

Bhardwaj, H.L. and A.A. Hamama. 2000. Oil, erucic acid and glucosinolate contents in winter hardy rapeseed germplasms. Ind. Crops Prod. 12: 33-38.

Blackman, R.L. and V.F. Eastop. 1984. Aphids on the World's Crops: An Identification and Information Guide. John Wiley and Sons: Chi Chester, New York. pp. 466.

Brown J, J.P. McCaffrey, B.L. Harmon, J.B. Davis, A.P. Brown, D.A. Erickson. 1999. Effect of late season insect infestation on yield, yield components and oil quality of *Brassica napus*, *B. rapa*, *B. juncea* and *Sinapis alba* in the Pacific Northwest region of the United States. J. Agric. Sci. (132): 281-288.

Buntin, G.D. and P.L. Raymer. 1994. Pest status of aphids and other insects in winter canola in Georgia. J. Econ. Entomol. 87(4): 1097-1104.

Capinera, J.L. 2008. Encyclopedia of Entomology. 2nd ed. Springer Science + Business Media. B.V. www.springerlink.com/index/H022116240442850.html

Cheema, M.A., M. A. Malik and S.M.A. Basra. 2001. Comparative growth and yield performance of different brassica varieties. Int. J. Agri. Bio. 3(1): 135–137.

Choudhury S. and S. Pal. 2009. Population dynamics of mustard aphid on different Brassica cultivars under terai agro-ecological conditions of West Bengal. J. Plant Protec. Sci. 1(1): 83-86.

Cole, R.A. 1997. The relative importance of glucosinolates and amino acids to the development of two aphid pests *Brevicoryne brassicae* and *Myzus persicae* on wild and cultivated brassica species. Entomol. Exp. Et. Appli. 85(2): 121-133

Cornell University, 2006. Plant defense against insects. Impact statement 2006. http://vivo.cornell.edu/display/individual31007.

Degenhart, D.F. and Z.P. Kondra. 1984. Relationships between seed yield and growth characters, yield components and seed quality of summer-type oilseed rape (*Brassica napus* L.). Euphytica, 33:885-889.

Deshpande, V.G. 1937. Cabbage Aphis - *Brevicoryne brassicae* - and Its Control with Home-Made Nicotine Spray. Agric. and Live-Stock in India. 7(6): 756-762.

Downey, R.K and G.F. Rakow. 1987. Rapeseed and mustard. In: Principles of Cultivar Developments. W .R. Fehr (Ed.) Macmillan Publishing Co., New York, 2: 437-486.

Engqvist. G.M. and H.C. Becker. 1993. Correlation studies for agronomic characters in segregating families of spring oilseed rape (*Brassica napus*). Hereditas. 118(3): 211-216.

FAOSTAT. 2004. Agriculture Data. Food and Agricultural Organization of the United Nations. February 2004. http://apps.fao.org/page/collections?subsetDagriculture

Farhatullah, S. Ali and F. Ullah. 2004. Comparative Yield Potential and other Quality Characteristics of Advanced Lines of Rapeseed. Int. J. Agri. Biol., 6(1): 203–205.

Farrell, J.A.K. 1977. Plant resistance to insects and the selection of resistant lines. N.Z. Entomol. 6(3): 244-261.

Flint, M. L. 1985. Green Peach Aphid, *Myzus persicae*. pp. 36-42. Integrated Pest management for Cole Crops and Lettuce. University of California Publication 3307. pp. 112.

Free, J.H.R. and I.J. Williams. 1978. A survey of damage caused to crops of oil seed rape (*Brassica napus*) by insect pest in south central England, and their effect on seed yield. J. Agric. Sci. 90: 417-24.

French, R.T. 1977. Oriental and brown mustard seed production. Techniques Bull. 2: 1-2.

Gangapur, D.R., B.G. Prakash, P.M. Salimath, R. L. Ravikumar and M. S. L. Rao. *2009*. Correlation and path analysis in Indian mustard (*Brassica juncea* L. Czern and Coss). Karnataka J. Agric. Sci. 22(5): 971-977.

Gill, R.S. and Bakhetia, D.R.C. 1985. Resistance of some *Brassica napus* and *B. campestris* strains to *Lipaphis erysimi* (Kaltenbach). J. Oilseeds Res. 2(1): 227-239.

Gilani, M.M., B. Hussain, K. Aziz. 1993. Estimation of correlation and genetic variability in various turnip rape types (*Brassica campestris* L. var. sarson). J. Agric. Res. 31(3): 267-271

Graser, G., B. Schneider, N.J. Oldham and J. Gershenzon. 2000. The methionine chain elongation pathway in the biosynthesis of glucosinolates in *Eruca sativa* (Brassicaceae). Archives Biochem. Biophysics, 378: 411-419.

Grundy, M.D. 1987. Monounsaturated fatty acids, plasma cholesterol and coronary heart disease. Am. J. Clin. Nutri. 45: 1168-75.

Hamid, S. and S. Ahmad 1980. Biological assessment of three different insecticides sprayed against *Lipaphis erysimi* (Kaltenbach) on winter oil-seed crops. Proc. Pak. Congr. Zool. 293-290.

Han, J. X., 1990, Genetic analysis of oil content in Rape (*Brassica juncea*). Oil Crop China, 2: 1-6.

Islam, M.S., L. Rahman and M.S. Alam 2009. Correlation and path coefficient analysis in fat and fatty acids of rapeseed and mustard. Bangladesh J. Agric. Res. 34(2): 247-253

Jatoi. M.Y., J. Humayun and S.A. Kakakhel. 2002. Relative resistance among 22 *Brassica napus* cultivars against Turnip Aphid, *Lipaphis erysimi* Kalt. Asian J. Plant Sci. 1(5): 558-559.

Jeromela, A.M., R. Marinkovic, A. Mijic, M. Jankulovska and Z. Zdunic. 2007. Interrelationship between oil yield and other quantitative traits in rapeseed (*Brassica napus* L.). J. Central Eur. Agric. 8(2): 165-170.

Jeromela, A.M., R. Marinkovic, A. Mijic, Z. Zdunic, S. Ivanovska and M. Jankulovska. 2008. Correlation and path analysis of quantitative traits in winter rapeseed (*Brassica napus* L.). Agriculturae Conspectus Scientificus, 73(1): 13-18.

Katiyar, R.P. and B. Singh. 1974. Interrelationship among yield and its components in Indian mustard. Indi. J. Agric. Sci. 44: 187-9.

Kaushik, N. 1998. Separation and quantification of quality parameters in rapeseed mustard. In *Abstract of 3Int. Symp. and short course on separation sciences*. 15 pp. 23-26 Nov. 1998. Bhopal: Regional Res. Lab.

Kawada, K. and T. Murai. 1979. Short Communication. Entomologia experimentalis et applicata. 26: 343-345.

Kelm, M. and H. Gadomski. 1995. Occurrence and harmfulness of the cabbage aphid (*Brevicoryne brassicae* L.) on winter rape. *Materially Sesji Instytutu Ochrony roslin*, 35: 101–103

Khalil, I.A., F. Manan, and S. Rehman. 1989. Nutritional aspects of Brassica Oilseed crops. Sarhad J. Agric. 11(5):13-22.

Khan, F.A., S. Ali, A. Shakeel, A. Saeed and G. Abbas. 2006. Correlation analysis of some quantitative characters in *Brassica napus* L. J. Agric. Res. 44(1): 7-14.

Khan, S., Farhatullah and I.H. Khalil 2008. Phenotypic correlation analysis of elite $F^{3:4}$ brassica populations for quantitative and qualitative traits. J. Agric. Biol. Sci. 3(1): 38-42.

Khan S., Farhatullah, I.H. Khalil, I. Munir, M.Y. Khan and N. Ali. 2008a. Genetic variability for Morphological traits in F3:4 Brassica populations. Sarhad J. Agric. 24(2):217-222.

Khan, S. Farhatullah, I.H. Khalil, M.Y. Khan and N. Ali. 2008b. Genetic variability, heritability and correlation for some quality traits in $F^{3:4}$ brassica populations. Sarhad J. Agric. 24(2): 223-232.

Khan, S.M. and H.A. Begum. 2005. Population dynamics of canola aphid and varietals performance of canola varieties against it in D.I. Khan, Pakistan. Pak. Entomol. 27(2): 37-41.

Khattak, S.U. and M. Hamed. 1993. Effect of different dates of sowing of rapeseed on aphid (*Brevicoryne brassicae* L.) infestation. Proc. Pak. Cong. Zool. 13: 249-254.

Kieckhefer, R.W. and J.L. Gellner, 1992. Yield losses in winter wheat caused by low density cereal aphid population. Agron. J. Medison. Wis., Americ. Soc. Agron. 84(2): 180-183.

Kishaba, A.N. and G.R. Manglitz. 1965. Non-preference as a mechanism of sweet clover and alfalfa resistance to the sweet clover aphid and the spotted alfalfa aphid. J. Econ. Entomol. 58: 566-569.

Kogan, M. and E.F. Ortman. 1978. Antixenosis - a new term proposed to define Painter's "nonpreference" Modality of Resistance. Bull. Entomol. Soc. Am. 24:175-176.

Kogan, M. 1982. Plant Resistance in Pest Management. In: Introduction to Insect pest Management. Metcalf, R. L and W.H. Luckmann. (ed.) John Wiley & Sons New York. pp. 93-134.

Kumar, P.R., T.P. Yadava. 1978. Selection criteria for seed yield in *Brassica campestris* L. 5th International Rapeseed Conference, Malmo, Sweden, GCIRC, pp. 63-65.

Kumar S., J.S. Chauhan, A. Aruna, M.L. Meena. 2010. Pattern of Glucosinolate Changes in Indian mustard (*Brassica Juncea* L.) During Different Developmental Stages. Indian J. Plant Physiol. 15(1): 69-72.

Landin, J. 1982. Life history, population dynamics and dispersal in the mustard aphid, *Lipaphis erysimi*: A literature study, 18 p. Swedish University of Agricultural Research, Research Information Centre. Uppsala (Sweden).

Lavkopr, R.A., P.L. Velnerus, O.T. Ichkolovr, V.L.R. Kuc and Oiskohou. 2006. Estimation of fatty acid content in intact seed of oil seed rape (Brassica napus L.) lines using Near-Infra red Spectroscopy. Czech J. Genet. Plant Breed. 42(4): 132-136.

Leto C., A. Carrubba and G. Furnari. 1996. Possibility of introduction of some high erucic Brassicaceae for industrial use into the semi-arid Sicilian environment. J. Agron. 30(4): 617-628

Liu, H.Y. and S. Q. Daozheng 1993. Path Coefficiency Analysis of the Yield Losses of Rape Caused by Rape Aphids. Journal of Northwest Sci-Tech University of Agriculture and Forestry. http://en.cnki.com.cn/Journal_en/D-D000-XBNY-1993-01.htm

Liu, T.X., J. Sparks and N. Alton. 2001. Aphids on Cruciferous Crops Identification and Management. http://hdl.handle.net/1969.1/87054

Mailer, R.J., Colton, R.T. and O'Bree, B.L. 1998. Quality of Australian Canola. Canola Association of Australia. ISSN 1322-9397.

Malik, M.A., A.S. Khan, M.A. Khan, B.R. Khan, A.S. Mohmand. 2000. Study of correlation among morphological parameters in different varieties/ accessions of brassica species, Pak. J. Biol. Sci. 3(7): 1180-1182.

Malik, M.A., I. Aziz, H.Z. Khan and M.A. Wahid. 2004. Growth, Seed yield and oil content Response of Canola (*Brassica napus* L.) to varying Levels of Sulphur. Int. J. Agric. Biol. 6(6): 1153-1155.

Malik R.S. 1988. Comparative aphid tolerance in cultivated species of Brassica. New Botanist, 165 (2-3): 113-116.

Mamun M.S.A., M.H. Ali, M.M. Ferdous, M.A. Rahman, M.A. Hossain (2010). Assessment of several mustard varieties resistance to mustard aphid, *Lipaphis erysimi* (Kalt.). J. Soil Nature 4(1): 34-38.

Metcalf, C. L. and W.P. Flint. 1962. Destructive and Useful Insects Their Habits and Control. McGraw-Hill Book Company; New York, San Francisco, Toronto, London. pp.1087.

MINFAL 1995. Oil Seed Development Strategies. National Oil Seed Development Project. Ministry of Food, Agric. & Livest. Govt. of Pakistan. pp.120.

MINFA, 2009. Agricultural Statistics of Pakistan. Statistics Division, Ministry of Economic Affairs and Statistics, Government of Pakistan. pp. 59-60.

MINFA, 2010. Pakistan Economic Survey 2009-10. Government of Pakistan, Finance Division (Economic Advisor's Wing) Islamabad. pp. 21-22.

Mohan, J.N., K. Krishnaiah and N. K. Krishna Kumar. 1981. Chemical Control of Mustard Aphid, *Lipaphis erysimi* Kalt and Leaf Webber, *Crocidolomia binotalis* Zell on Cabbage. Pesticides. 15(2) 29-32.

Munthali D.C. 2009. Evaluation of Cabbage Varieties for Resistance to the Cabbage Aphid. Afric. Entomol. 17(1):1-7.

Naazar, A, F. Javidfar, E. Jafarieh E, and M. Mirza. 2003. Relationship among yield components and selection criteria for yield improvement in winter rapeseed (*Brassica napus* L.). Pak. J. Bot. 35(2): 167-174.

Ogrodowczyk, M. and M. Wawrzyniak. 2004. Adoption and path-coefficient analysis for assessment of relationship and interrelationship of yield and yield parameters of winter oilseed rape. Rosliny Oleiste/Oilseed Crops, 25(2): 479- 491

Ozer, H., E. Oral and U. Dogru. 1999. Relationship between yield and yield components on currently improved spring rapeseed cultivars. Turk. J. Agric. For. *23*:603-607

Packard, C. M. and J. H. Martin. 2010. Resistant Crops, the ideal way. http:Science-in-farming-library4farming.org/open-source.html.

Pathak, H.C., F.P. Chaudhary and S.K. Dixit. 1984. Selection criteria for seed yield in mustard (*Brassica juncea* L.). Madras Agric. J. 71: 758-62.

Patil A. and K. B. Goud. 2004. Determination of Economic Injury Level of *Athalia lugens* and *Lipaphis erysimi* on Mustard. Karnataka J. Agric. Sci. 17(4): 828-830.

Paula, S.V.de., M.C. Picanco, F.H. Koga and J.C.de. Moraes, 1995. Resistance of seven clones of kale to *Brevicoryne brassicae* (L.) (Homoptera: Aphididae). Anais da Sociedade Entomologica do Brasil, 24: 99–104.

PARC. 1991. Oilseed Crops of Pakistan. Pak. Agri. Res. Council, Islamabad. pp. 147.

PARC. 1998. Oilseed Crops of Pakistan. Pakistan Agricultural Research Council (PARC) IDRC: Library: Documents: Oilseed Processing (Pakistan). archive.idrc.ca/library/document/091017/chap3_e.html

Painter, R. H. 1951. Insect resistance in Crop Plants, The University press of Kansas, Lawrence. 520 p.

Pallot, T.N., A.S. Leong, J.A. Allen, T.M. Golder, C.F. Greenwood and T. Golebiowski. 1999. Precision of fatty acid analyses using near infrared spectroscopy of whole seed Brassicas. 10th Int. Rapeseed Conf. Canberra, Australia.

Patel, S.P. and R.N. Pokharkar. 1982. Some new records of insect pests infesting cruciferous vegetable crops in Moharastra State. Rev. Appl. Ent. (A) 70(7): 495.

Patel, S. R., A.K. Awasthi and R.K.S. Tomar. 2004. Assessment of yield losses in mustard due to mustard aphid. Applied Ecology and Environmental Research 2(1):1–15. http://www.ecology.kee.hu . ISSN 1589 1623.

Rahman, I.U., H. Ahmad, Inamullah, Sirajuddin, I. Ahmad, F.M. Abbasi, M. Islam and S. Ghafoor. 2009. Evaluation of rapeseed genotypes for yield and oil quality under rain-fed conditions of district Mansehra. Afric. J. Biotechnol. 8(24): 6844-6849.

Rasool R. 2010. Effect of Morphological Plant Characters towards Resistance against Aphids on Wheat. M.Sc. Thesis. Department of Zoology. GC University, Faisalabad. 84 p.

Rehman, K.A., M. Munir and A. Yousaf. 1987. Rape and Mustard in Pakistan. PARC Islamabad. 101 p.

Rohilla , H.R., M. Singh, U.K. Kalra and S.S. Kharub, 1987. Losses caused by cabbage aphid (*Brevicoryne brassicae* Linn) in different Brassica genotypes. Proc. 7th Int. Rapeseed Cong., Poland. 5: 1077-1083.

Roy, S. K. and K. Baral. 2002. Population dynamics of mustard aphid, *Lipaphis erysimi* (Kaltenbach) as influenced by a biotic factors and different rapeseed mustard genotypes. Int. J. Indust. Entomol. 4(1): pp. 69-76.

Rustamani, M.A., U.F. Qaimkahni, G.H. Munshi and A.B. Chutto. 1998. Efficacy of different insecticides against Mustard aphid. Sarhad J. Agric. 4: 659-664.

Rakow, G., P.J. Raney, and D. Males. 1995. Field performance of canola quality Brassica juncea. Proc., 9th Int. Rapeseed Congr. Dorchester, UK. 2: 428-30.

Reinhardt, T. C., and G. Robbelen. 1991. Quantitative Analysis of Fatty Acids in Intact Rapeseed by Near Infrared Reflectance Spectroscopy. GCIRC Cong. pp. 1380-1384.

Sachan G.G and J.P. Purwar. (2007). Integrated Insect Pest Management in Rapeseeds and mustard. In Entomology: Novel Approaches, 007.Eds. Jain and M.C. Bharava, pp 399-423. Web. www.bookfactoryindia.com

Saljoqi, A.U.R., M.S. Din, S. Ahmad and Karimullah, 2001. Effect of sowing dates and cultivar tests of canola against aphid population. Sarhad J. Agric., 17: 623-628.

Sarwar, M., N. Ahmad, Q.H. Siddiqui, A. Ali and M. Tofique. 2004. Genotypic response in canola (*Brassica* Species) against aphid (Aphidae: Homoptera) attack. The Nucleus, 41(1-4) 87-92.

Shah, A.H., M. M. Gilani and F.A. Khan. 2000. Comprehensive selection of yield and yield influencing characters in *Brassica species*. Int. J. Agric. Biol. 2(3): 245–247.

Shah, S.A., R. Zamir and S.T. Shah. 2007. Development of a new high yielding canola quality rapeseed variety Durr-E-Nifa for general cultivation in NWFP. Pak. J. Bot. 39(7): 2475-2481.

Shoaib, U. 2003. Spatio-temporal distribution of aphid ((*Brevicoryne brassicae* L.) in Canola (*Brassica napus* L.). M.Sc. Thesis. University College of Agriculture, Bahauddin Zakariya University, Multan. 65 p.

Singh, B. and D.R.C. Bakhetia. 1987. Screening and breeding techniques for Aphid resistance in Oleiferous Brassica: A review. Oilcrops Network, International Development Research Centre, Canada. 50 p.

Singh, C.P. and G.C. Sachan. 1994. Assessment of yield losses in yellow sarson due to mustard aphid, *Lipaphis erysimi* (Kalt). J. of Oilseeds Res. 11(2): 179-184.

Singh, R.K. and B.D. Chaudhry. 1979. Biometrical methods in quantitative genetic analysis. Kalyani Publ. New Delhi. 304 p.

Singh, S. R., A. Narain, K.P. Srivastava and J.A. Siddiqui. 1965. Fecundity of Mustard Aphid of Different Rapes and Mustard Species. Ind. Oilseeds J. 9(3): 215-219.

Singh, S.V. and Y.P. Malik. 1989. Population dynamics and economic threshold of *Lipaphis erysimi* on mustard. Indi. J. Entomol. 60: 43-49.

Siraj-ud-din. 2000. Insect Pests of Sarson (*Brassica Campestris*) and Chemical Control of Mustard Aphid *Lipaphis erysimi* (Kalt.). M.Sc. Thesis, Department of Entomology, NWFP Agricultural University, Peshawar. 71 p.

Suri, S.M., D. Singh and K.S. Brar. 1988. Estimation of losses in yield of brown sarson due to aphids in Kangra Valley. I. Effect of crop growth stages and aphid feeding exposure. J. Insect Sci. 1: 162-167.

Swati, Z.A. 2005. Genetic Improvement of Brassica Oilseed by Integrated use of conventional and Molecular Biological Approaches. Institute of Biotechnology and Genetic Engineering, NWFP Agricultural University, Peshawar. Project Final Completion Report of ALP Project. 33 p.

Tahir M,A. Ali, M.A. Nadeem, A. Tanveer and Q.M. Sabir, 2007. Performance of Canola (*Brassica napus* L.) under different irrigation levels. Pak. J. Bot., 39(3): 739-746.

Toba, H. H. 1962. Studies on the Host Range of Watermelon Mosaic Viruses in Hawaii. Plant Dis. 46: 409-410.

Tuncturk, M. and V. Ciftci. 2007. Relationships between yield and some yield components in rapeseed (*Brassica napus* ssp. *Oleifera* l.*)* cultivars by using correlation and path analysis. Pak. J. Bot. 39(1): 81-84

USDA, 2011. Crop Production Tables. Rapeseed Area, Yield, and Production (Table 15). http://ffas.usda.gov/wap/circular/2007/07-02/tables.html

Vekaria, M.V. and G.M. Patel (2000). Screening of promising Brassica and allied genotypes for resistance against mustard aphid. Indi. J. Entomol. 62(1): 37-42

Velasco, L., C. Mollers and H.C. Becker. 1999. Estimation of seed weight, oil content and fatty acids composition in intact single seeds of rapeseed Brassica napus by near infrared reflectance spectroscopy. Euphytica, 106: 79-85.

Weiss, E.A. 1983. Oil seed crops. British library cataloging in Publication data: pp. 61-215

Woyke, T. 1981. The variability and mutual relationship of characters of significance in the evaluation of varieties and lines of winter Swede rape free of erucic acid. Biuletyn Instytutu Hodowli I. Aklimatyzaeji Roslin, 146: 17-23.

Yadav, P. R., L. S. Yadav and S. S. Dashad. 1988. Comparative efficacy of some insecticides against the aphid, *Lipaphis erysimi* Kalt. on cabbage crop. IndI. J. Entomol. 50(1): 61-68.

Zwolferadn, H., and G. Harris. 1971. Host specificity determination of insects for biological control of weeds. Ann. Rev. Entomol. 16: 157-178.

CHAPTER – VIII

APPENDIX

8.1. Aphids Density Analysis on 12 Genetically Modified Brassica Genotypes

8.1.1. Aphids Density 2006-07

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	2651.19	241.018	18.60	0.0000
Replications	3	150.92	50.306	3.88	0.0176
Error	33	427.62	12.958		
Total	47	3229.74			

Coefficient of Variation = 19.55%
LSD at 0.05 alpha level = 2.990

8.1.2. Aphids Density 2007-08

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	4933.91	448.537	11.62	0.0000
Replications	3	281.48	93.827	2.43	0.0826
Error	33	1273.85	38.602		
Total	47	6489.24			

Coefficient of Variation = 18.90%
LSD at 0.05 alpha level = 5.160

8.1.3. Aphids Density 2006-07 and 2007-08 (Combined)

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	2029.75	184.523	13.63	0.0000
Replications	3	178.85	59.617	4.40	0.0103
Error	33	446.80	13.539		
Total	47	2655.40			

Coefficient of Variation = 14.35%
LSD at 0.05 alpha level = 3.056

8.2 Aphids Density and Yield Components of 12-Genetically Diversified Brassica Genotypes (Two-Years Average Field Data)

8.2.1. Plant Height

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	13607.55	1237.050	59.72	0.0000
Replications	3	57.97	19.325	0.93	0.4358
Error	33	683.62	20.716		
Total	47	14349.15			

Coefficient of Variation = 2.59%
LSD at 0.05 alpha level = 3.780

8.2.2. Primary Branches

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	440.84	40.076	77.47	0.0000
Replications	3	0.62	0.206	0.40	0.7554
Error	33	17.07	0.517		
Total	47	458.53			

Coefficient of Variation = 7.45%
LSD at 0.05 alpha level = 0.597

8.2.3. Siliqua Main Raceme^{-1}

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	8308.92	755.356	72.33	0.0000
Replications	3	45.52	15.173	1.45	0.2452
Error	33	344.61	10.443		
Total	47	8699.05			

Coefficient of Variation = 6.46%
LSD at 0.05 alpha level = 2.684

8.2.4. Siliqua Length

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	94.56	8.596	182.25	0.0000
Replications	3	0.07	0.023	0.49	0.6940
Error	33	1.56	0.047		
Total	47	96.18			

Coefficient of Variation = 3.43%
LSD at 0.05 alpha level = 0.180

8.2.5. Seed Siliqua^{-1}

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	809.41	73.582	318.75	0.0000
Replications	3	0.56	0.187	0.81	0.4978
Error	33	7.62	0.231		
Total	47	817.59			

Coefficient of Variation = 3.39%
LSD at 0.05 alpha level = 0.399

8.2.6. Seed Yield Plant^{-1}

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	952.85	86.623	34.59	0.0000
Replications	3	8.18	2.726	1.09	0.3675
Error	33	82.63	2.504		
Total	47	1043.66			

Coefficient of Variation = 6.81%
LSD at 0.05 alpha level = 1.314

8.2.7. 1000 Seeds Weight

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	9.00	0.818	7.30	0.0000
Replications	3	0.64	0.212	1.89	0.1506
Error	33	3.70	0.112		
Total	47	13.34			

Coefficient of Variation = 8.09%
LSD at 0.05 alpha level = 0.278

8.2.8. Seed Yield kg ha^{-1}

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	5598792.23	508981.112	5.50	0.0001
Replications	3	1314632.23	438210.743	4.73	0.0074
Error	33	3054228.52	92552.379		
Total	47	9967652.98			

Coefficient of Variation = 20.13%
LSD at 0.05 alpha level = 252.685

8.2.9. Biological Yield ha^{-1}

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	75024235.72	6820385.066	9.90	0.0000
Replications	3	21453526.86	7151175.621	10.38	0.0001
Error	33	22743181.72	689187.325		
Total	47	119220944.30			

Coefficient of Variation = 6.05%
LSD at 0.05 alpha level = 689.531

8.3. Biochemical Analysis of 12 Genetically Diversified Brassica Genotypes

8.3.1. Oil (%)

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	283.27	25.752	2.31	0.0313
Replications	3	14.21	4.736	0.42	0.7367
Error	33	368.17	11.157		
Total	47	665.66			

Coefficient of Variation = 6.75%
LSD at 0.05 alpha level = 4.805

8.3.2. Protein (%)

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	78.77	7.161	0.97	0.4902
Replications	3	66.46	22.153	3.00	0.0443
Error	33	243.30	7.373		
Total	47	388.54			

Coefficient of Variation = 12.19%
LSD at 0.05 alpha level = 4.011

8.3.3. GSL Contents (u mol/g)

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	15112.47	1373.861	5.81	0.0000
Replications	3	1220.31	406.771	1.72	0.1818
Error	33	7801.37	236.405		
Total	47	24134.15			

Coefficient of Variation = 16.86%
LSD at 0.05 alpha level = 22.12

8.3.4. Moisture (%)

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	34.45	3.132	9.30	0.0000
Replications	3	0.46	0.153	0.45	0.7166
Error	33	11.12	0.337		
Total	47	46.03			

Coefficient of Variation = 9.13%
LSD at 0.05 alpha level = 0.8351

8.3.5. Oleic Acid (%)

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	3262.60	296.600	33.28	0.0000
Replications	3	19.22	6.406	0.72	0.5479
Error	33	294.08	8.912		
Total	47	3575.91			

Coefficient of Variation = 6.70%
LSD at 0.05 alpha level = 4.295

8.3.6. Linolenic Acid (%)

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	90.56	8.232	11.36	0.0000
Replications	3	1.90	0.634	0.88	0.4639
Error	33	23.91	0.725		
Total	47	116.37			

Coefficient of Variation = 8.79%
LSD at 0.05 alpha level = 1.225

8.3.7. Erucic Acid (%)

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	1699.00	154.455	6.84	0.0000
Replications	3	126.93	42.310	1.87	0.1534
Error	33	745.53	22.592		
Total	47	2571.47			

Coefficient of Variation = 10.66%
LSD at 0.05 alpha level = 6.838

8.4 Aphids Density and Seed Yield Losses in 12 Brassica Genotypes under Screen house Conditions at Flower-bud initiation Stage

8.4.1. Seed Yield Losses (%) with Five (5) Aphids/Plant

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	4269.10	388.100	4.82	0.0008
Replications	2	398.14	199.068	2.47	0.1077
Error	22	1772.73	80.578		
Total	35	6439.96			

Coefficient of Variation = 32.64%
LSD at 0.05 alpha level = 7.600

8.4.2. Seed Yield Losses (%) with Ten (10) Aphids/Plant

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	5994.70	544.972	4.80	0.0009
Replications	2	1166.05	583.027	5.13	0.0148
Error	22	2499.08	113.594		
Total	35	9659.83			

Coefficient of Variation = 26.24%
LSD at 0.05 alpha level = 9.024

8.4.3. Seed Yield Losses (%) with Fifteen (15) Aphids/Plant

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	5570.36	506.397	8.01	0.0000
Replications	2	367.21	183.605	2.90	0.0760
Error	22	1391.24	63.238		
Total	35	7328.82			

Coefficient of Variation = 14.42%
LSD at 0.05 alpha level = 6.733

8.5 Aphids Density and Yield Components under Screen house Condition

8.5.1 Average Aphids Density in Screen House Experiment

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	22341.95	2031.086	7.36	0.0000
Replications	2	27943.79	13971.895	50.60	0.0000
Error	22	6074.46	276.112		
Total	35	56360.19			

Coefficient of Variation = 18.17%
LSD value at 0.05 alpha = 14.067

8.5.2. Average Seed Yield in Untreated Control in Screen House

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	34.93	3.175	11.51	0.0000
Replications	2	0.96	0.480	1.74	0.1986
Error	22	6.07	0.276		
Total	35	41.95			

Coefficient of Variation = 9.86%
LSD at 0.05 alpha level = 0.445

8.5.3. Average Seed Yield in Treated Plants in Screen House

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	21.00	1.909	7.21	0.0000
Replications	2	16.58	8.292	31.32	0.0000
Error	22	5.82	0.265		
Total	35	43.41			

Coefficient of Variation = 16.76%
LSD at 0.05 alpha level = 0.436

8.5.4. Average Percent Seed Yield Losses under Screen House Conditions

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	3991.16	362.833	4.47	0.0014
Replication	2	5812.37	2906.183	35.82	0.0000
Error	22	1784.99	81.136		
Total	35	11588.51			

Coefficient of Variation = 21.31%
LSD at 0.05 alpha level = 7.626

8.5.5. Average Straw Yield in Untreated Control in Screen House

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	258.71	23.519	6.17	0.0002
Replications	2	17.64	8.818	2.31	0.1226
Error	22	83.91	3.814		
Total	35	360.26			

Coefficient of Variation = 8.07%
LSD at 0.05 alpha level = 1.654

8.5.6. Average Straw Yield in Treated Plants in Screen House

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	128.91	11.719	2.76	0.0205
Replications	2	339.64	169.822	40.00	0.0000
Error	22	93.40	4.245		
Total	35	360.26			

Coefficient of Variation = 12.57%
LSD at 0.05 alpha level = 1.744

8.5.7. Average Percent Straw Yield Losses under Screen House Conditions

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	2940.79	267.345	6.00	0.0002
Replications	2	5452.69	2726.347	61.20	0.0000
Error	22	980.00	44.546		
Total	35	9373.49			

Coefficient of Variation = 21.01%
LSD at 0.05 alpha level = 5.651

8.5.8. Average Plant Height in Untreated Control in Screen House

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	15205.06	1382.279	21.87	0.0000
Replications	2	141.87	70.934	1.12	0.3434
Error	22	1390.25	63.193		
Total	35	16737.18			

Coefficient of Variation = 4.96%
LSD at 0.05 alpha level = 6.730

8.5.9. Average Plant Height in Treated Plants in Screen House

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	15204.33	1382.212	24.54	0.0000
Replications	2	14984.67	7492.333	133.00	0.0000
Error	22	1239.33	56.333		
Total	35	31428.33			

Coefficient of Variation = 6.94%
LSD at 0.05 alpha level = 6.355

8.5.10. Average Percent Plant Height Losses under Screen House Conditions

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	544.19	49.472	1.72	0.1347
Replications	2	5971.67	2985.837	103.72	0.0000
Error	22	633.32	28.787		
Total	35	7149.19			

Coefficient of Variation = 16.28%
LSD at 0.05 alpha level = 4.543

8.5.11. Average Number of Branches in Untreated Control in Screen House

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	132.89	12.081	42.62	0.0000
Replications	2	0.60	0.299	1.05	0.3657
Error	22	6.24	0.283		
Total	35	139.72			

Coefficient of Variation = 6.85%
LSD at 0.05 alpha level = 0.451

8.5.12. Average Number of Branches in Treated Plants in Screen House

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	111.76	10.160	139.38	0.0000
Replications	2	3.46	1.730	23.74	0.0000
Error	22	1.60	0.073		
Total	35	116.83			

Coefficient of Variation = 3.93%
LSD at 0.05 alpha level = 0.229

8.5.13. Average Percent Branches Loss under Screen House Conditions

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	976.36	88.760	15.90	0.0000
Replications	2	517.02	258.509	46.31	0.0000
Error	22	122.80	5.582		
Total	35	1616.18			

Coefficient of Variation = 20.15%
LSD at 0.05 alpha level = 2.000

8.5.14. Average Number of Siliquae mr^{-1} in Untreated Control in Screen House

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	1996.89	181.535	16.76	0.0000
Replications	2	37.72	18.861	1.74	0.1986
Error	22	238.28	10.831		
Total	35	2272.89			

Coefficient of Variation = 10.11%
LSD at 0.05 alpha level = 2.786

8.5.15. Average Number of Siliquae mr^{-1} in Treated Plants in Screen House

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	1482.44	134.767	32.66	0.0000
Replications	2	169.01	84.504	20.48	0.0000
Error	22	90.78	4.126		
Total	35	1742.23			

Coefficient of Variation = 8.51%
LSD at 0.05 alpha level = 1.720

8.6.16. Average Percent Siliquae mr^{-1} Losses under Screen House

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	2411.10	219.191	4.20	0.0020
Replications	2	1877.07	938.535	17.98	0.0000
Error	22	1148.09	52.186		
Total	35	5436.26			

Coefficient of Variation = 26.55%
LSD at 0.05 alpha level = 6.116

8.5.17. Average Number of Leaves in Untreated Control in Screen House

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	971.39	88.308	10.99	0.0000
Replications	2	31.72	15.861	1.97	0.1628
Error	22	176.78	8.035		
Total	35	1179.89			

Coefficient of Variation = 8.48%
LSD at 0.05 alpha level = 2.400

8.5.18. Average Number of Leaves in Treated Plants in Screen House

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	977.32	88.848	27.99	0.0000
Replications	2	135.92	67.961	21.41	0.0000
Error	22	69.84	3.175		
Total	35	1183.09			

Coefficient of Variation = 6.25%
LSD at 0.05 alpha level = 1.509

8.5.19. Average Percent Leaves Losses under Screen House Conditions

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotypes	11	1894.48	172.225	7.27	0.0000
Replications	2	1157.62	578.808	24.42	0.0000
Error	22	521.47	23.703		
Total	35	3573.57			

Coefficient of Variation = 33.14%
LSD at 0.05 alpha level = 4.122

8.6. Average Aphids Density and Biochemical Contents in all the 12 Genotypes under Screen House Conditions

8.6.1. Average Oil Contents in all the 12 Genotypes in Untreated Control

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	347.65	31.605	18.46	0.0000
Replication	2	1.02	0.510	0.30	0.7453
Error	22	37.66	1.712		
Total	35	386.33			

Coefficient of Variation = 3.04%
LSD at 0.05 alpha level = 1.108

8.6.2. Average Oil Contents in all the 12 Genotypes in Treated Plants

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	337.75	30.704	8.82	0.0000
Replications	2	1.87	0.935	0.27	0.7669
Error	22	76.61	3.482		
Total	35	416.23			

Coefficient of Variation = 4.47%
LSD at 0.05 alpha level = 1.580

8.6.3. Average Percent losses in Oil Contents in all the 12 Brassica Genotypes

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	210.79	19.163	2.47	0.0343
Replication	2	6.19	3.094	0.40	0.6760
Error	22	170.76	7.762		
Total	35	387.74			

Coefficient of Variation = 57.34%
LSD at 0.05 alpha level = 2.359

8.6.4. Average Protein Contents in all 12 Genotypes in Untreated Control

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	84.53	7.685	1.27	0.3057
Replication	2	14.28	7.138	1.18	0.3272
Error	22	133.56	6.071		
Total	35	232.36			

Coefficient of Variation = 10.07%
LSD at 0.05 alpha level = 2.086

8.6.5. Average Protein Contents in all the 12 Genotypes in Treated Plants

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	104.93	9.539	5.31	0.0004
Replication	2	4.70	2.348	1.31	0.2906
Error	22	39.49	1.795		
Total	35	149.12			

Coefficient of Variation = 4.84%
LSD at 0.05 alpha level = 1.134

8.6.6. Average Percent Change (losses/gain) in Protein Contents in all the 12 Brassica Genotypes

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	1523.49	138.499	1.29	0.2920
Replication	2	415.28	207.638	1.94	0.1680
Error	22	2358.46	107.203		
Total	35	4297.23			

Coefficient of Variation = 73.16%
LSD at 0.05 alpha level = 8.766

8.6.7. Average Glucosinolates in all the 12 Genotypes in Untreated Control

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	43810.25	3982.750	39.49	0.0000
Replications	2	25.38	12.688	0.13	0.8824
Error	22	2218.73	100.851		
Total	35	46054.36			

Coefficient of Variation = 10.03%
LSD at 0.05 alpha level = 8.503

8.6.8. Average Glucosinolates in all the 12 Genotypes in Treated Plants

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	37390.27	3399.115	37.17	0.0000
Replication	2	111.77	55.886	0.61	0.5517
Error	22	2011.65	91.439		
Total	35	39513.69			

Coefficient of Variation = 8.98%
LSD at 0.05 alpha level = 8.096

8.6.9. Average Percent Change (losses/gain) in Glucosinolates in all the 12 Brassica Genotypes

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	2703.83	245.803	2.16	0.0595
Replications	2	86.79	43.397	0.38	0.6870
Error	22	2500.18	113.645		
Total	35	5290.80			

Coefficient of Variation = 68.01%
LSD at 0.05 alpha level = 9.026

8.6.10. Average Moisture Contents in all the 12 Genotypes in Untreated Control

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	29.42	2.674	10.60	0.0000
Replications	2	0.35	0.173	0.68	0.5149
Error	22	5.55	0.252		
Total	35	35.32			

Coefficient of Variation = 9.01%
LSD at 0.05 alpha level = 0.425

8.6.11. Average Moisture Contents in all the 12 Genotypes in Treated Plants

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	34.16	3.105	28.67	0.0000
Replications	2	0.02	0.012	0.11	0.8961
Error	22	2.38	0.108		
Total	35	36.56			

Coefficient of Variation = 6.17%
LSD at 0.05 alpha level =

8.6.12. Average Percent Losses in Moisture Contents in all the 12 Brassica Genotypes

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	1098.51	99.865	1.94	0.0890
Replications	2	11.36	5.679	0.11	0.8959
Error	22	1130.45	51.384		
Total	35	2240.33			

Coefficient of Variation = 81.78%
LSD at 0.05 alpha level = 6.069

8.6.13. Average Oleic Acids in all the 12 Genotypes in Untreated Control

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	4467.32	406.120	68.92	0.0000
Replications	2	26.52	13.258	2.25	0.1291
Error	22	129.64	5.893		
Total	35	4623.47			

Coefficient of Variation = 4.94%
LSD at 0.05 alpha level = 2.055

8.6.14. Average Oleic Acids in all the 12 Genotypes in Treated Plants

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	3515.90	319.627	76.21	0.0000
Replication	2	3.06	1.530	0.36	0.6984
Error	22	92.27	4.194		
Total	35	3611.23			

Coefficient of Variation = 4.16%
LSD at 0.05 alpha level = 1.734

8.6.15. Average Percent Change (losses/gain) in Oleic Acid in all the 12 Brassica Genotypes

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	870.01	79.092	5.23	0.0005
Replications	2	0.70	0.350	0.02	0.9772
Error	22	332.61	15.119		
Total	35	1203.32			

Coefficient of Variation = 61.57%
LSD at 0.05 alpha level = 3.292

8.6.16. Average Linolenic Acids in all the 12 Genotypes in Untreated Control

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	83.34	7.576	21.83	0.0000
Replication	2	0.40	0.200	0.58	0.5702
Error	22	7.64	0.347		
Total	35	91.37			

Coefficient of Variation = 5.80%
LSD at 0.05 alpha level = 0.499

8.6.17. Average Linolenic Acid in all the 12 Genotypes in Treated Plants

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	67.13	6.103	7.32	0.0000
Replications	2	2.72	1.359	1.63	0.2189
Error	22	18.35	0.834		
Total	35	88.20			

Coefficient of Variation = 8.94%
LSD at 0.05 alpha level = 0.773

8.6.18. Average Percent Change (losses/gain) in Linolenic Acid in all the 12 Brassica Genotypes

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	760.09	69.099	1.37	0.2544
Replications	2	76.90	38.448	0.76	0.4786
Error	22	1109.93	50.451		
Total	35	1946.92			

Coefficient of Variation = 89.93%
LSD at 0.05 alpha level = 6.014

8.6.19. Average Erucic Acid in all the 12 Genotypes in Untreated Control

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	4076.30	370.572	61.75	0.0000
Replications	2	3.40	1.698	0.28	0.7562
Error	22	132.02	6.001		
Total	35	4211.72			

Coefficient of Variation = 5.61%
LSD at 0.05 alpha level = 2.074

8.6.20. Average Erucic Acid in all the 12 Genotypes in Treated Plants

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	2432.98	221.180	21.31	0.0000
Replications	2	12.51	6.255	0.60	0.5561
Error	22	228.32	10.378		
Total	35	2673.81			

Coefficient of Variation = 6.94%
LSD at 0.05 alpha level = 2.728

8.6.21. Average Percent Change (losses/gain) in Erucic Acid in all the 12 Brassica Genotypes

A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Genotype	11	3244.74	294.977	3.25	0.0090
Replications	2	135.98	67.991	0.75	0.4847
Error	22	1998.30	90.832		
Total	35	5379.02			

Coefficient of Variation = 71.64%
LSD at 0.05 alpha level = 8.069

9.1. Metrological Data for the months of January, February and March, 2007

Date	Avg.-Temp.	Avg. -RH	Avg.-Rain	Date	Avg.-Temp.	Avg. -RH	Avg.-Rain	Date	Avg.-Temp	Agri	Avg.-Rain
01.01.07	8.7	86	0	01.02.07	12.1	64	0	01.03.07	12.6	81	0
02.01.07	8.8	87	0.2	02.02.07	13.1	61	0	02.03.07	12.3	81	0
03.01.07	7.8	70	0	03.02.07	11.6	71	0	03.03.07	15	65	0
04.01.07	6.9	71	0	04.02.07	14.2	74	1.4	04.03.07	9.3	92	11.2
05.01.07	6.3	72	0	05.02.07	13.3	76	0	05.03.07	10.8	83	0
06.01.07	5.7	73	0	06.02.07	13.4	81	0	06.03.07	12.1	68	0
07.01.07	5.4	70	0	07.02.07	14	68	0	07.03.07	14.6	64	0
08.01.07	5.5	71	0	08.02.07	13.4	67	0	08.03.07	14.9	65	0
09.01.07	7	65	0	09.02.07	15.5	67	0	09.03.07	17.4	62	3.6
10.01.07	7.5	70	0	10.02.07	12.7	88	28.4	10.03.07	12.2	84	11.8
11.01.07	7.3	66	0	11.02.07	10	94	77	11.03.07	15.1	76	0
12.01.07	7.1	64	0	12.02.07	9.6	94	46.6	12.03.07	11.6	91	12.6
13.01.07	6.7	64	0	13.02.07	10	94	11.4	13.03.07	12.1	83	2.6
14.01.07	6.3	64	0	14.02.07	8.8	91	0	14.03.07	10.4	89	0
15.01.07	7.1	64	0	15.02.07	12.3	85	0	15.03.07	13.1	74	0.2
16.01.07	7	68	0	16.02.07	11.3	86	31.4	16.03.07	15	73	0
17.01.07	7.5	70	0	17.02.07	12	80	0	17.03.07	15.9	72	0
18.01.07	8	74	0	18.02.07	11.8	81	0	18.03.07	18.6	63	0
19.01.07	6.3	85	0	19.02.07	9.4	94	0	19.03.07	17.8	74	0
20.01.07	8.3	60	0	20.02.07	12.4	75	0	20.03.07	15.9	87	0
21.01.07	8.3	58	0	21.02.07	13.6	68	2.8	21.03.07	16.2	80	0
22.01.07	7.9	59	0	22.02.07	10.4	90	0	22.03.07	14	83	0
23.01.07	8.7	60	0	23.02.07	11.3	74	2	23.03.07	16.7	71	0.2
24.01.07	10.9	58	0	24.02.07	12.5	69	0	24.03.07	17.6	58	0.2
25.01.07	10.7	69	0	25.02.07	14.1	69	0	25.03.07	17.5	61	0
26.01.07	13.8	64	0	26.02.07	14	73	0	26.03.07	18.4	63	0
27.01.07	14.8	61	0	27.02.07	13.6	82	2.6	27.03.07	18.9	67	0
28.01.07	12.5	69	0	28.02.07	10.7	96	10.4	28.03.07	21	62	0
29.01.07	13.5	63	0					29.03.07	22.4	65	0.4
30.01.07	13.6	63	0					30.03.07	23.6	60	0.4
31.01.07	13.5	60	0					31.03.07	24.2	60	0.2

Source: KPK Agriculture University Peshawar.

9.2. Metrological Data for the months of January, February and March, 2008

Date	Avg. Temp.	Avg. RH	Avg. Rain mm	Date	Avg. Temp.	Avg. RH	Avg. Rain mm	Date	Avg. Temp.	Avg. RH	Avg. Rain mm
01.01.08				01.02.08	27	48	0	01.03.08	14	75	0
02.01.08				02.02.08	26	76	0	02.03.08	13.5	68	0
03.01.08				03.02.08	20	76	0	03.03.08	16.5	69	0
04.01.08	12	73	0	04.02.08	24	77	0	04.03.08	15	78	9.4
05.01.08	12.5	50	0	05.02.08	20	78	1.01	05.03.08	12.5	68	0
06.01.08	17.5	48	0	06.02.08	23	89	0	06.03.08	14	38	0
07.01.08	15	46	0	07.02.08	25	61	0	07.03.08	16.5	62	0
08.01.08	10	38	0	08.02.08	26	17	0	08.03.08	16	53	0
09.01.08	11	72	0	09.02.08	22	78	0	09.03.08	19	88	14
10.01.08	11	62	0	10.02.08	18	88	40.64	10.03.08	13.5	69	0
11.01.08	11.5	50	0	11.02.08	11	88	101.6	11.03.08	15.5	88	2
12.01.08	11	59	0	12.02.08	12	87	101.6	12.03.08	15.5	88	18
13.01.08	9.5	43	0	13.02.08	12	88	2.54	13.03.08	12.5	88	0
14.01.08	10.5	30	0	14.02.08	13	88	21	14.03.08	12.5	68	14
15.01.08	10	32	0	15.02.08	18	88	53.34	15.03.08	14	69	0
16.01.08	10	60	0	16.02.08	17	89	0	16.03.08	17	80	0
17.01.08	10.5	85	0	17.02.08	20	88	0	17.03.08	18.5	72	0
18.01.08	10.5	63	0	18.02.08	20	88	0	18.03.08	20	39	0
19.01.08	7.5	73	0	19.02.08	20	67	0	19.03.08	20	90	0
20.01.08	10	52	0	20.02.08	19	78	0.27	20.03.08	17.5	71	32
21.01.08	14	30	0	21.02.08	19	88	6.86	21.03.08	17.5	80	1
22.01.08	11	41	0	22.02.08	14	88	1.01	22.03.08	15.5	71	0
23.01.08	12.5	32	0	23.02.08	20	34	0	23.03.08	19	59	0
24.01.08	14.5	74	0	24.02.08	25	36	0	24.03.08	19.5	57	0
25.01.08	14.5	52	0	25.02.08	25	52	0	25.03.08	19.5	74	0
26.01.08	17.5	62	0	26.02.08	23	69	0	26.03.08	20.5	67	0
27.01.08	17	43	0	27.02.08	19	88	2.06	27.03.08	20.5	53	0
28.01.08	17	62	0	28.02.08	12	88	9.02	28.03.08	23.5	68	0
29.01.08	18	52	0					29.03.08	24	50	0
30.01.08	18	43	0					30.03.08	24.5	91	0
31.01.08	16.5	48	0					31.03.08	20.5	76	0

Source: Pakistan Forest Institute, Peshawar.