DEVELOPING AND IMPLEMENTING STRATEGIC IPM MODULE OF SUGARCANE STEM BORER *CHILO INFUSCATELLUS* (PYRALIDAE, LEPIDOPTERA)

By

Shahbaz Ahmad
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DECLARATION

I hereby affirm that the contents of this thesis “Developing and Implementing strategic IPM module of sugarcane stem borer” (*Chilo infuscatellus*, Pyralidae, Lepidoptera), are the product of my own research and no part has been copied from any published source (except the references, standard mathematical or genetic models / equation / protocols etc.). I further declared that this work has not been submitted for award of any other diploma/ degree. The university may take action if the information provided is found inaccurate at any stage.

(Shahbaz Ahmad)
2001-ag-1088

The Controller of Examinations,
University of Agriculture,
Faisalabad.

We, the members of Supervisory Committee, certify that all changes recommended by external examiner(s) have been incorporated by **Mr. Shahbaz Ahmad, Reg. No. 2001-ag-1088.** Now it is recommended for the award of the degree.

SUPERVISORY COMMITTEE:

1) Chairman _____
Prof. Dr. Muhammad Ashfaq (T.I.)

2) Member _____
Prof. Dr. Mansoor-ul-Hassan

3) Member _____
Prof. Dr. Shahbaz Talib Sahi

DEDICATED

TO

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ABSTRACT

Studies were carried out on integrated management of sugarcane stem borer, (*Chilo infuscatellus)* in the Punjab, Pakistan during 2008-09. The objectives of the studies to screen out the comparatively resistant varieties and also to find out the impact of abiotic factors. The use of chemical, biological, cultural, mechanical controls and their integration were also tested after 10, 15 and 20 days intervals. Fifteen varieties were tested during 2008 and the minimum infestation was recorded in US-718 (14.45%), which was statistically at par with those of US-312 (14.80%), CPF-246 (14.90%) and significantly different from varieties US-4191, US-676, US-133, US-824, CPF-234 and CPF-237 that showed 15.02, 15.28, 15.72, 15.83, 15.90 and 15.95% infestation. From the preliminary screening, US-718 and US-312 having least infestation with 14.45% and four varieties US-4191, US-678, US-133, US-824 showing intermediate infestation (15.02%, 15.28%, 15.72%, 15.83%) and three varieties US-824, CPF-234 and CPF-237 having maximum infestation 15.83, 15.90 and 15.95% were selected. The impact of abiotic factors indicated that maximum temperature did not affect the infestation level significantly whereas the minimum temperature showed a significant and positive correlation to infestation with r-values 1.00, 0.065, 1.00 and 0.036 during 2008-09 respectively. The relative humidity showed significant correlation having positive response to infestation with r-values of 0.637 and 0.520 during 2008-09 collectively. The effect of rainfall on the stem borer infestation was highly significant with r - values of 0770 and 0.781 during 2008-09 cumulatively. The variety US-133 contained maximum nitrogen and fat contents, which were calculated to be 1.147% and 2.20%, respectively. The highest recovery was recorded to be 11.74% in variety US-312, whereas the lowest in SPF-234 which was 8.12%. Plant girth and leaf area were comparatively higher in US-824 SPF-234 with 5.47 cm^2 and 4.66 cm^2 as compared with other varieties. The CPF-246 possessed maximum Phosphorous quantity (0.244%), whereas minimum contents were found in US-778 (0.191%). The concentration of Potassium was comparatively higher in SPF-234 (0.243%) and maximum quantity of Calcium was calculated in variety US-1491 (0.249%). Maximum Magnesium-contents were found in variety SPF-234, which were calculated to be 0.240% and maximum Copper was recorded in variety CPF-237 (4.25ppm). The lowest Ferrous was recorded in US-312 with 31.70ppm and minimum Manganese was recorded in US-312 (30.73ppm) while maximum Zinc present in SPF-234 with 22.60ppm. The results of insecticides against the sugarcane stem showed minimum infestation by Furadan followed by Thimet, Padan and Monomehypo with which showed 10.22%, 11.35%, 12.45% and 13.84% respectively, after 15 days interval. In case of cultural and mechanical control, the minimum infestation (12.91%) was recorded by using Trash mulching while in case of biological control, minimum infestation (9.31%) was recorder by using 72000 *Trichogramma* eggs after 10 days interval while the integration of *Trichogramma* cards, detrashing and light traps showed minimum infestation (8.71%) after 10 days interval.

Chapter-1

INTRODUCTION

Sugarcane *(Saccharum officinarum*) is a main cash crop of Pakistan. It is grown for sugar and sugar related products. In addition to sugar production, sugarcane produces many valuable by-products like alcohol used by pharmaceutical industry, begasse use for paper ethanol used as a fuel, and chip board manufacturing and also for the burning of sugar mills furnaces and press mud is used for organic matter and nutrients for crop production. This crop is grown in three province of Pakistan namely in Punjab, Sindh and NWFP. Total area of sugarcane in Pakistan during 2003-04 was 10, 75,000 hectares with production of 537, 76,000 tonns. The average yield of sugarcane per hectare, this year is 63.9 million tons which is 16.8 percent higher than that of the last year (Anonymous, 2007-08). Pakistan ranks fifth in cane acreage, sixth in cane production and stands at 15th position in the average cane yield per hectare, in sugarcane producing countries of the world. But average yield of sugarcane, in Pakistan, is very low as compared to that of the other sugarcane growing countries of the world (Ansari, 1974). Although crop occupies an important place in cropping pattern of Pakistan and brings large dividends to growers. This may be due to many factors like limited irrigation source, lack of high potential varieties, imbalance use of fertilizers, use of poor technology and most important issue is the insect pests.

About 103 insects are related with Sugarcane crop (Kumarasinghe, 1999). In Pakistan, 12 species of insect pests have been reported to be associated with the sugarcane crop (Chaudhry and Ansari, 1988). The sugarcane stem borer *Chilo infuscatellus* has been reported from, Korea, Formosa, Asia, India, Malaya, Afghanistan and Philippines. In Pakistan, it is distributed and occurrence has been in Punjab and NWFP provinces (Cheng *et al.*, 1997; Hashmi, 1994). In Pakistan it was reported in 11 districts of Punjab Pakistan viz. Gujrat, Sheikhupura, Sahiwal, Pak Patin, T.T Singh, Kasur, Khaniwal, Okara, M. Bahauddin, Muzafar Ghar and Layyah to find the attack of sugarcane borers on different sugarcane varieties during, November 1999. The maximum borer infestation was recorded 12.37% in Okara and 15.21% in Pak Patin and 13.56% in District Sahiwal and the minimum infestation of 1.73% was recorded in Muzafarghar (Aheer *et al.*, 2003).

The predominant species causing damage are the sugarcane borers, especially sugarcane stem borer (Ashraf and Fatima, 1980). It was reported that losses caused by stem borer of sugarcane are up to 36.51% (Aheer *et al*., 1994). Sugarcane borer is most serious pest of sugarcane due to its feeding inside as well as to a lot of existence problems created by wide-ranging use of insecticides in large number of insect pests (Mohyuddin *et al*., 1997; Soerjani, 1998). Sugarcane borers make tunnels in stubbles and internodes as result, food supply to aerial parts of stem and leaves become stopped. According to Gupta and Singh (1997) damaged at 3rd and 4th brood of sugarcane borers may result more than 25% reduction in weight.

The resistant varieties are a better choice to reduce the use of insecticides and also to obtain a sustainable sugarcane production. The varietal resistance for the control of insect pests to provide no additional cost and it also safe the environmental population. According to Glaz (2000) sugarcane production could never be improved until and unless resistance varieties and modern technologies are adopted on large scale. As all the existing commercial sugarcane varieties are, unfortunately, susceptible to sugarcane stem borer attack, it has become very important to find out the resistance new sugarcane varieties resistant sugarcane stem borer. Nazir *et al*. (1997) also reported that higher cane yield is the function of higher genetic potential of a variety.

Weather factors play very important role on insect pest in the field. The mortality factors affect the various levels like the effect of temperature more than 40°C in June and relative humidity below 40 percent in second and third instar in month of May, (Roy., 1983). Certain limits sustain and are not favour to their multiplication and progress; therefore, it results in serious outbreaks of different insect pests. Insects are dependent on the environmental temperature to maintenance their activity. The enclosure of physical factors like, humidity adds the dynamic climatology associated to the cited studies of entomology. The effect of climatic factors also effect on the percentage infestation of sugarcane stem borers. The occurrence of stem borer was regularly recorded during first and second week of April (Mehmood *et al.*, 1989). The effects of weather factors on the population of sugarcane stem borer with special reference to relative humidity, temperature and rainfall should be studied. It is also important to analyze and verify by critical experiments, theoretical relationships and normally proposed between abiotic factors and the population dynamics of

sugarcane insects. The experiments with populations in the controlled environments and statistical correlations based on the field data will allow a much comprehensive understanding of the significance of climate and reveal the potential for improving pest control methodology through this understanding. The results obtained can be utilized as a base line to develop a sustainable IPM for achieving improved management of *Chilo infuscatellus,* on sugarcane.

Keeping in view the severity of the problem, chemical insecticides are considered to be a quick method for the control of insect pests but the extensive use of pesticides kills the natural enemies, thus resulting in sudden flare up of pest population (Hamburg and Guest, 1997). The use of chemical control to reduce the pest population of borers is also very effective. Gupta and Roy (1982), Rana *et al*. (1992) and Khan and Jan (1994) reported that Furadan 3-G and Basudin 10-G@ 25 Kg/ha not only significant reduce the stem borer infestation but also increase the yield. Marwat and Khalid (1985), Mishra *et al.* (1998) reported that seven granular insecticides were applied against the sugarcane borer and found that Furadan 3G and Desyston showed very good results. The use of monocrotophos against *Chilo infuscatellus* showed lowest dead hearts percentage was 9.2% and highest cane yield was 110.7 t/ha while the economic threshold level (ETL) of pest was 15.46. It has been reported that more than 500 pest species have developed resistance against insecticides (Georghion and Lagunes, 1991). An indiscriminate use of pesticides has created many serious problems like, Pest resistance, the resurgence of secondary pests as primary pests, environmental pollution, hazards to human being and other living organisms over and above the cost of control.

To minimize such problems, the use of bio-control is a very effective alternative. For this purpose, therefore the use of *Trichogramma chilonis* against the sugarcane stem borers can give very positive results. *Trichogramma* has been considered as one the most important parasitoid for more than 100 years and it was also reported that *Trichogramma chilonis* can be more effective, when it's parasitizing potential and searching ability is well adopted in the field (Smith, 1996). The inundate releases of bio-agents for the control of lepidopterous pests are being practiced in more than 32 million hectares each year around the world (Hassan, 1993). *Trichogramma chilonis* was introduced to control the sugarcane borers. The release of *Trichogramma chilonis* in China, Switzerland, Canada and former USSR reduced the damage upto 70-92% on sugarcane (Lily, 1994), while in Asia, reduced the incidence of

sugarcane early stem borer (*Chilo infuscatellus)* by 43 and 82% (Bharati *et al*., 2002). %. The use of biocontrol against the sugarcane stem borer is very effective. Rafique *et al.* (2007) reported that *Trichogramma chilonis* give very good results against the *against* sugarcane stalk borer. The application of *Trichogramma chilonis* @ 60,000 eggs reduces the pest infestation 83% against the *Chilo infuscatellus*. Zia *et al*. (2007) reported that the application of *Trichgramma chilonis* against *Chilo infuscatellus* showed a negative correlation with an increase in number of eggs which indicated that it can successfully used to control stem borer and it reduce the borer infestation 2.74%. Mustafa *et al.* (2006) studies that infestation of *Chilo infuscatellus* was reduced 52.04 % during 2000 and 60.03% during 2001. The damage ranged from 3.9 to 10.5% in treated and 9.6 to 18.6% in untreated plots. The internodes damaged reduction due to *Trichogramma* treated ranged from (28.6 to 59.7%). Shenhmar *et al*. (2003) reported that released of *Trichogramma chilonis* @ 50000 per acre at 10 days interval from July to October. In term of borer infestation the damaged was 52.04% during 2000 and 60.03% during 2001.

Khan and Khan (2006) reported that IPM techniques i.e. cultural, mechanical chemical and biological control methods and in combinations for borers control in sugarcane crop. Gul and Saeed (2006) suggested that methods like chemical, cultural, mechanical and biological and their combinations give significantly borers controls and increase the sugarcane yield. Sardana (2000) stated that by adopting various techniques like use of light traps application of insecticides and release of biological control agent *Trichogramma chilonis* effectively control the sugarcane borers. Zubir *et al.* (2007), Jena *et al.* (1997), Hashmi and Rehman, (1985) reported that the IPM approach was very effective against sugarcane borers. The release of egg parasite *Trichogramma chilonis* @ 20000 eggs/acre and trash mulching between rows was successfully controlled the sugarcane borers. The earthing-up in May- June, detrashing, removing shoots and applications of fertilizers during pre monsoon season, gave very good results against sugarcane stem borer. The use of integration of various control against the sugarcane stem borer *Chilo infuscatrllus* showed very good results

Keeping in view the importance of sugarcane borers, this experiment was carried out to study the effect of different control methods on sugarcane borers and cane and sugar yields in sugarcane plant to overcome this complex situation in which integrated pest management

is the most desired approach. In IPM, all possible methods are utilized in a compatible manner to obtain the best control against insect pests with at least disturbance of environment. Therefore, in the present studies various control methods are integrated for the management of the sugarcane stem borer with the following objectives;

1. To find out the resistant varieties against sugarcane stem borer *(Chilo infuscatellus)* on the basis of pest infestation.
2. To determine the physico-chemical plant factors which are responsible for the insect pests resistance.
3. To asses the bio-efficacy of selective insecticides, against the sugarcane stem borer.
4. Integration of the bio-control agent *Trichogramma chilonis* with other control methods against the sugarcane stem borer.
5. To find out the economical, suitable and sustainable techniques for the integrated management of sugarcane stem borer.

Chapter-2

REVIEW OF LITERATURE

2.1 Varietal Resistance/Infestation:

The early and mid maturing varieties of sugarcane CP.75/344, CP.73/1030 and CP.72/2086 were comparatively more tolerant to shoot and root borers attack while the variety CP.69/1059 and CP.71/1442 tolerant to stem borer. The CP.69/1059 and CP.77/400 were resistant to these stem borers. The varieties CP.72/356, US.626, CP.72/370, N.88-2 and US-421, CP.73/2109 and US.630 were found resistant to stem borer (Jan, 1992, 1993 and 1995). It was also reported that (Mushtaq *et al*., 1989) ten varieties of sugarcane viz., BF-162, BF-158, BF-164, BF-161-, BF-159, and CPF (HF)-160, BF-163, BL-4, BF-165, BF-166 and the variety CPF (HF)-160 showed resistance while BF-166 was found to be least. The data was collected after 15 days interval by using hand net and light traps which revealed that 11720 specimens belonging to different insect orders captured in 3 localities, 117 species were related to sugarcane including borers. In early maturing varieties, SPF-237 dead heart percentage was 2.97%, The DHP was 3.30% in mid maturing variety CPF82-1172 and it was18.34% in late maturing variety S97-SP-27 (Ahmad *et al.*, 2003; Munir *et al*., 2008).

The twelve sugarcane varieties CPF- 237, S-842-1-28, S-86-US-340, S-95-HS-185, NSG-311, LPHS-35, BF-138, Q-88, LRK-2001, S-96-SP-302 Malakand-16, and Malakand-17 were tested during 2002-03. The variety S-96-SP-302 showed maximum yield 137.78 t/ha, thick 3.31 cm and long 260 cm. The variety S-95-HS-185 and Q-88 showed yield 134.67 and 106.92 t/ha respectively. The Malakand-17 showed minimum yield 51.33 t/ha. S-95- HS-185 showed maximum recovery of 10.63% and Brix 22.40%. The LPHS-35 and S-96-SP-302 showed recovery10.32 and 9.88%. The S-95-HS-185 and S-96-SP-302 showed best varieties in the area (Shah *et al.*, 2005). The studies showed that varieties MT 70-611, S94-HS-229, and LCP 81-10 showed better results than standard varieties CP 77-400 and CPF-237 in term of yield. The varieties CPF-236, HSF-240 and LCP 81-10 were at par with CPF-237. The varieties CP 77-400, CPF-237 and CPF-236 showed high yield. HSF-240 and LHO 83-153 gave better results than other

varieties. The HSF-240 out yielded all 6 varieties than standards CPF-237 and CP 77-400. The varieties, S96-SP-574, SPF-234, HSF-240, CPF-235 and S96-SP-302 showed equally high yield (187.70, 103.20, 114.01 181.10 and 124.12 t/ha, respectively as showed CPF-237 and CP 77-400, 145.00 and 121.56 t/ha, respectively. The CPF-237 showed best excellence performance. It was also reported that the varieties S-97- US-183 and CP 77-400 showed the maximum cane yield113.89 t/ha but the statistically at par with other varieties. Variety S-97-US-183 showed the maximum cane sugar yield of 14.83 t/ha (Sarwar *et al.,* 2002; Kahloon *et al.,* 2003).

The variety S97-US-102, S96-SP-574, S98-SP-133, S96-SP-571, CPF-243, HSF-240, S87-US-1873, AEC84-347, NSG-60 and NSG-555 were tested. The variety S87-US-1873 showed better results followed by HSF-240. The variety CPF-243 showed high yield and statistically at par with variety HSF-240. The variety AEC-84-347 showed minimum yielded 52.38 t/ha while CPF-243 showed sugar yield 12.78 t/ha and AEC-84-347 showed lowest 6.37 t/ha. Similarly 546 varieties were tested with standard variety CP-77-400. The 148 varieties were chosen while 72.84 varieties were discarded. So, 13.18 %, 2.74%, 0.366%, 1.28%, 24.17 %,8.60%, 4.21%, 27.32%, 0.549% and 10.43 % varieties were rejected due to poor growth, , low Brix percentage, pithiness, aerial roots, sprouts, disease susceptibility, cracks, insect infestation, and lodging, hairiness respectively. The sugarcane varieties CP-77-400, SPF-234, CPF-237, S94-HS-87, SS94-HS-229, MT 70-611 and S94-HS-92 showed densities 50000, 75000 and 100000. The maximum yield 131.25 t/ha during 1999-2000 was showed with density of 75000 DBS/ha while the varieties, S94-HS-229 gave the maximum cane yield, followed by SPF-234 with 133.70 and 126.10 t/ha in 1999-2000 (Zafar *et al.,* 2005; Rafiq *et al.,* 2007; Ali *et al.,* 2002). Similarly the damage of sugarcane internodes during 1984-94 at Taiwan Sugar research Institute Experimental Farm. They found that the percent infestation of different sugarcane borers was 33.8% by *Chilo infuscatellus,* 46.1% by *Tetramoera schistaceana,* and 19.7% by *Chilo sacchariphagus.* The *Chilo infuscatellus* has been reported from, Korea. Formosa, Asia, India, Malaya, Afghanistan and Philippines. In Pakistan, it is distributed and occurrence has been in Punjab and NWFP provinces (Cheng *et al.,* 1997; Hashmi, 1994). Another experiment was conducted in 11 districts of Punjab Pakistan viz. Gujrat, Sheikhupura, Sahiwal, Pak Patin, T.T Singh, Kasur,

Khaniwal, Okara, M. Bahauddin, Muzafar Ghar and Layyah to find the attack of sugarcane borers on different sugarcane varieties during, November 1999. From the results it was concluded that maximum borer infestation was recorded 12.37% in Okara and Pak Patin, 15.21% in Sahiwal followed by 13.56%, respectively and the minimum infestation of 1.73% recorded in Muzafarghar (Aheer *et al.*, 2003).

The study was conducted in Egypt which showed that there was positive correlation between the incidence and intensity of attack by *Chilo agarnemnon* in sugarcane variety GT-54/9 and a negative correlation between pest incidence and yield. The maximum yield except 52001-US-400 as compared to check variety L-116. The variety LRK-2004 showed maximum yield 186.21 after Ganj Bakhsh with 135.91 tones per hectare. The varieties Chandka and NIA-2004 produced very high yield with 129.23 and 128.39 tones per hectare respectively (Dooh, 1997; Sohu *et al.,* 2008). In another experiment (Bahadar *et al.,* 2007; Jena and Patnaik, 1996) worked was also done on 48 varieties of sugarcane. The maximum yield of 110.75t/ha with average 10.6 percent of sugar recovery was noted for variety Bannu-Green (S-84-I-282). The varieties CPF-237 and S-90-SP-57 showed the yield 108.31, 108.24t/ha with average recovery of 7.91 and 10.74% in plant stage. Similarly the variety Bannu-3 exhibited the highest average recovery 12.13 and 12.0% followed by CP-89/846 with average sugar recovery of 11.58 percent. It was also tested that stalk borer cause highest 10.61% in variety 85A-261and lowest cane weight 6.11% in CO. 8314 variety, determined in Nayagarh, Orissa. The 36 genotypes of sugarcane were sown and the Stem borer infestation was recorded 90 days. The results revealed that stem borer infestation was higher in sodic soil than the normal soil condition 34.7 and 20.6% respectively. The minimum infestation of stem borer was recorded in Colk-91238 and Cos-92263 with (14.3 and 12.1%). These two varieties Cos-93216 and Copaget-93227 were recommended due to low infestation of stem borer under both soils (Arvind *et al.,* 1996).

Ten varieties of sugarcane in response of top borer *Scirhophaga nivella* and stem borers *Chilo auriciliio)* showed that there were no varieties with combined resistance to top and stem. The variety M442-51 was moderately resistant to stem borer and varieties PO-130I6 and PS-56 were moderately resistance to top borer (Suhartawan, 1993). In this experiment nine sugarcane varieties were tested. The results

revealed that varieties HoTh-2109 and HoTh-332 produced maximum cane yield of 148.33 and 135.0 t ha-1 aligned with check variety Th-10, while the varieties HoTh-348, HoTh-311 and HoTh-316 produced next high yield of 129.33, 127.66 and 126.66 t ha-1, respectively, but the average yield in other varieties was low than the check variety Th-10. The quality performance showed that variety HoTh-311 showed maximum CCS of 14.64% followed by HoTh-2109, HoTh-344, HoTh- 348, HoTh-332 and HoTh-349, with CCS of 14.61, 14.50, 14.47, 14.36 and 14.16%, respectively against check variety Th-10 which showed CCS 14.06%. From the result it was concluded that varieties HoTh-2109, HoTh-332, HoTh- 348 and HoTh-311 were best. Similarly, 29 varieties of sugarcane were also tested against stalk borer. The results showed that nine varieties were resistant and 20 were moderately resistant against stalk borer. Infestation in the tested varieties was 1.09 to 3.84% against the standard variety PS-59 with 3.92% (Soomro *et al.,* 2007).

The twelve varieties of sugarcane COBLN-9102, COBLN- 9I04, CO-740, Ekora Kuhiyar, COBLN-910I, CO-997, COBLN-9103, CO-6315 and WL-22 were tested against *Scirpophaga excerplalis* and *Chilo tumidcostais*. The variety "Ekora Kuhiyar" was not showed infestation against plassy borer and top borer. The mean infestation of plassy borer and top borer was 1.15% and 1.08% on variety WI-22. The infestation was very high against the other varieties from 33.06 to 47.10% for top borer and 42.15 to 55.61% for plassy borer (Gupta and Singh, 1997). The effect of stalk borer on different varieties of sugarcane was tested at sugarcane breeding institute karnal. The results showed that cane setts damaged on the buds and near the buds were more effected at germination and tillering stage and it was also found that the setts maximum damage in the middle of internodes as result these setts could be sown with high seed rate (Kaloi *et al.,* 2007; Sardana *et al.*, 2000). The seventeen varieties of sugarcane (Thirumurugan *et al.,* 2000) were tested under field conditions at Sugarcane Research Station during 1998-99 to find out the resistance against stem borer *Chilo infuscatellus* and internode borer *C. sacchriphagus indicus.* The varieties G-93008, G-92394, G-93010 and SI-89083 were susceptible against stem borer and susceptible against internode borer. Two varieties G-93003 and G-92392 were susceptible against the shoot and internode borers. Gul *et al.* (2002) reported that 16 sugarcane varieties 8 each of

early and mid maturing groups during 1998-99 at sugar crops Research Institute, Mardan against shoot, Gurdaspur and root borers in both plant and ratoon crops. They reported that the variety Mardan-93 significantly received more infestation of borer in both crops compared to other candidate varieties in early maturing group. In mid maturing group variety received maximum borers infestation as compared to other varieties in both plat band ratoon crops. The results showed that variety COL-29 was found susceptible against the borers and showed the infestation from 15-90%, while the variety SPSG-79 showed zero% infestation against the borers. The-19 varieties of sugarcane were also tested against sugarcane borers. The varieties HOCP-97-609 and L-98-209 showed maximum bored internodes 10.47% and 12.65% respectively, while the varieties HOCP-85-845 showed the minimum bored internodes 3.95 % followed by L-98-207 and CP 77-321 at 601%, 4.18% respectively (Aheer *et al.,* 2003; Reagan *et al.,* 1997). The infestation of the pyralids *Scirpophaga excerptalis* and *Chilo tumidicostalis* was also studied on different sugarcane varieties at six levels of nitrogen. It was reported that the incidence of *Sexcejptalis* increased the levels of nitrogen. The low incidence of the pyralid was recorded 5.56%. The nitrogen did not show any effect on *Chilo twnidicostalis.* The different varieties did not affect by the *Scirpophaga excerplalis,* but the variety *Cv. CO.* 740 was the least affected by *C. tumidicostalis* (Saikia *et al.,* 1994). The ten sugarcane cultivars were tested at Madhya Pradesh, Sehore, India in 1993-94. The data of cane yield and diameter infestation with early stem borer *Chilo infuscatellus* and sugar yields were recorded. It was reported that yield was very high and pest infestation was very low in Co-7517. It was also reported that the chemical composition of sugarcane variety Coj-64 infested by *Chilo auricilius* showed sugar recovery percentage 9.85% in the un-infested canes which compared with 9.78, 9.35, 9.30, and 2.395 in canes showing 5, 10, 15, 40, 50 or 80 % infestation (Verma and Choudhary, 1998; Manineder *et al.,* 1998).

The work was also done on 29 varieties of sugarcane against stalk borer. The 14 varieties of sugarcane were sown to test the incidence against the stem borer in Shahjahanpur India. The percent of incidence was 2-3 to 5% against the stem borer in varieties Coj-64, Cos-88216 and Cos-90265. The results showed that average top borer damaged 2.20% and 1.31% by stem borer. It was further reported that sugar recovery

was reduced by stem borer 19.28% and by top borer 5.45% (Manager *et al.*, 1998; Ullah *et al.*, 2006). It was also studied that *Chilo infuscatellus* in sugarcane in India recorded that delayed the harvesting of the cane, availability of early ratoon sprouts for ovipositor and late tillers in the fields were the most important factors favoring the carry over of the pest to next season. Sugarcane harvested during spring could reduce the population build-up of the pest in the succeeding crops. The incidence against the stalk borer on various sugarcane varieties in Punjab India. Results showed that varieties Cos-88230, Cos-8436 and Coj-83, were most susceptible against the stalk borer (Saikia and Roy, 1998; Kanwar *et al.*, 1999).

The 18 varieties of sugarcane were tested for resistance against the *Chilo infuscatellus* during 1994-1995. The minimum infestation was recorded 3.89% during 1994 but during 1995 the highest infestation 20.15% was recorded in variety G-5291/85, followed by 17.92 and 16.25% infestation in ISD-20 varieties. These varieties showed highly susceptible against borer attack. The varieties LGC, G-251/85, G-308/85, ISD-24 and ISD-19 showed least infestation received by early stem borer from 1.97 to 4.56%. The different varieties of sugarcane against the *Chilo sacchariphagus* were tested daring 1992-93. They showed that varieties Co-7219, Co-87042, Co-87044, Si- 851247, Co-85-30, Co-85002 and Si-85057 were found resistant to the borers (Ahad *et al.*, 1999; Rajendran and Hanifa, 1996). It was reported that 16 varieties of sugarcane 8 each of early and mid maturing groups were tested against stem, root and gurdaspur borer at Sugar Crop Research Institute Mardan during 1993-1997. The result was based on the average infestation of borers in both crops. The mean infestation of stem borer was found lowest 0.36% and highest 0.80% for verities S-82, US-631 and CP-65/357 in early maturing series. The lowest infestation 0.38% was recorded in mid maturing varieties in CPF-145 and highest 0.79% in CPF-44/101 varieties. The lowest Infestation 16% was found in root borer and verities CP-72/256 and JN-88-2 showed highest infestation 10.29%. The lowest infestation 9.78% was recorded in mid maturing varieties S-82, US-630 and highest infestation was recorded 12.97% in CP-44/10. It was also noted that mid and late maturing varieties of sugarcane were tested against *Chilo infuscatellus* in India. The results revealed that variety Cos-767 showed most resistant and Cos-85002 showed most susceptible on the basis of sucrose content. The BL.4, Triton, PR.1000 and Tha-10 showed 2 to 4 internodes showed the reduction in

height from 1.34 to 2.69%. It was further reported, that the juice quality was also affected by the sugarcane borers. The decline in cane juice was statistically significant with the increase of borer infestation. (Jan *et al.,* 1999; Karnatak *et al.,* 1999; Tunio *et al.,* 2006).

2.2 Impact of Weather Factors on Infestation:

Weather factors play very important role for the pest population under the filed conditions. It was reported that mortality factors affect the various levels like relative humidity below 40 percent in second and third instar in month of May, while the temperature effect more 40°C in June (Roy *et al*., 1983). The effect of climatic factors also effect on the percentage infestation of sugarcane stem borers. The occurrence of stem borer was regularly recorded during first and second week of April. The correlation between temperature, humidity and stem borer infestation was non significant and positive (Mehmood, 1989; Rustamani *et al.*, 1997). It was also reported that temperature, rainfall and relative humidity increase the borer population 34.2, 29.5 and 25.3% three consecutive years, 1986, 1987 and 1988. Temperature showed positive and significant correlation with borer infestation. The cumulative effect was noted 9.40 percent. The hot weather reduced the borer development (Aheer *et al.,* 1994; Nagaraja and Chanty; 1957; Long and Concienne, 1964).

Reseachers have also studied fluctuations in population of sugarcane top, stem, root and Gurdaspur borers after exposure of artificial lighting. The maximum populations of stem, top, root and Gurdaspur borers were noted during 4th week of May, 4th week of August and 2nd week of September, 1987. The maximum temperature 34-37°C and minimum temperature 20-27°C and relative humidity 52-70% were effect the borer population. It was reported that stem borer caused maximum damage during April and infestation increased up to 21.44% in September. The root borer damage during month of April and caused maximum damage of 10.21% in August while Gurdaspur borer caused damage in month of June with 2.63% up to July. The 46 varieties were screened out. The nine were highly susceptible, three were susceptible, six were less susceptible, one was moderately susceptible and twenty-seven were resistance. It was also reported that rainfall and relative humidity showed positive response against the sugarcane borer during both years separately and cumulatively while the temperature showed negative

respond towards the infestation (Bhati *et al.*, 2008; Rana *et al.*, 1992 and Shah *et al.*, 1981).

2.3 Physico-Morphological, Chemical and Qualitative Factors:

Khaliq *et al.* (2005) worked on Morpho-physio, chemical and qualitative factors of plat and relationship with pest infestations. They investigated that leaf thickness, moisture contents showed positive and significant correlation with the pest infestation. They also reported that there was non significant correlation between total minerals, copper and manganese with the pest infestation. The relationship between nitrogen, calcium, magnesium, potassium and ferrous contents was positive while carbohydrates, fats, Phosphorous and zinc showed significant and adverse effect on the pest infestation, while the POL, Brix contents and CCS showed negative on pest infestation. Junejo *et al.* (2004) studied the effect of micronutrients on the quality of sugarcane varieties CP-65/357 during 1989/90 and 1990/91 in Mardan, Pakistan. The treatments showed that control, 0.50, 1.00 and 1.50 kg Cu/ha, 1.50, 3.00 and 4.50 kg Zn/ha; 0.25, 0.50 and 0.75 kg Boron/ha; and 1.00, 2.00 and 3.00 kg Mn/ha. From the results it was concluded that the lowest rates of Cu, Zn, and B resulted in high cane Brix. The effect of other micronutrients on POL, fiber% and commercial cane sugar was also calculated. Similar worked was done on different sugarcane varieties to evaluate the yield components during 2002-03 in Pakistan. They obtained the varieties S-96-SP-571, S-96-SP-574 and S-97-SP-183 from Faisalabad, HS-4 and HS-12 from Habib Sugar Mills Nawabshah, S-87- US-1873 and S-88-US-436 from Mardan, AEC-86-347 from Tandojam and Gulabi-95, NSG-555 and NSG-60 from Jhang. They reported that AEC-86-347 produced maximum yield 100.91 mt/ha while the minimum yield obtained from S-96-SP-574 which was 76.15 mt/ha. All the varieties showed (CCS) percentages of 11% while low CCS percentages of 10.75 and 10.66% were obtained from S-96-SP-574 and NSG-60 while average yield was obtained from NSG-555. It was also reported that the juice quality in sugarcane variety CO.6315 damaged by *Chilo tumidcostalis* and *Scirpophaga excerplalis* in Assam, India in 1995-96. The contents of Brix, POL and CCS were reduced in damaged canes by 4.21%, 10.0% and 12.28%, respectively (Baloch *et al.*, 2005; Gupta and Singh, 1997). Another experiment was conducted to evaluate quantitative

and qualitative characteristics of eleven sugarcane varieties during 2000-02 and 2003. The percentage of different varieties were recorded as height cm, Brix %, cane thickness mm, number of internodes, millable stool and cane yield (t ha^{-1}) were notated. The Results showed that variety Th-10 showed better results of cane yield more than yield component followed by Th-34, AEC–86-347. The correlation coefficient values of yield characters were positive. The maximum value of correlation of cane yield was recorded from millable canes r = 0.726 and plant height r = 0.53 8 (Somroo *et al.*, 2007). It was also reported that stalk height, cane girth, number of internodes per stalk, number of millable, cane yield/ha and qualitative characters like Brix percentage, purity, POL percentage, and sugar recovery parameters were recorded. The maximum cane girth was calculated in Th-10, 26.2 mm while the NIA-98 showed maximum number of internodes per stalk 21.9. The stalk weight was maximum in Th-10, 217 cm. The variety Th-10 showed 113 t/ha maximum average cane yield. The maximum sugar recovery was noted for Th-10 11.43%, So based on the performance, the most promising variety Th-10, Th-33 and Th-34 were recommended for development under the conditions of Thatta (Keerio *et al*., 2003).

The variety Th-10 showed maximum stalk length 210 cm, cane girth 26.9 mm, Brix 23.7% and number of internodes per stalk 22.9.The varieties Th-34 and Th-33 showed maximum number of millable canes/m2 in Th-34, 22.2, Th-33, 21.0 and Th-10 20.2). The maximum cane yield was recorded in varieties Th-34, Th-10 and Th-33 with 116, 115 and 112 t/ha, respectively. The sugarcane varieties AEC86-347, AEC82-1026, CP67-412, AEC86-328 and BL4 were also evaluated during 1999-2000 and 2000-01.The performance of these varieties were tested on the basis of cane length, cane girth, number of stalks, and weight per stool, cane yield and commercial cane sugar in Sindh, Pakistan. The performance of variety AEC86-347 was maximum with Brix values more than 1 for cane yield, CCS and sugar yield. It was concluded that the potential of this variety was very good produce high yields at different locations under favorable environment. Different varieties were tested against the sugarcane stem borer The interaction between stem borer's infestation and plant height was positive with r^2=0.984, There was negative relation between infestation and plant girth, while the plant Brix showed no relation with stem borer infestation (Memon *et al.*, 2003; Khan *et al.*, 2004 and Khan *et al.*, 2006).

2.4 Chemical Control:

The insecticide Curator 3-G, Sevidol 4:4 G and Basudin 10G @ 25 Kg/ha was applied after earthing up to reduce the infestation of stem and root borer at level 2.81, 7034 and 17.89% and to increase the cane yield up to 56.88, 56.62 and 44.31 tons/ha along with highly sugarcane yield of 7.86, 7.39 and 5.95 tons/ha in sugarcane crop (Khan and Jan, 1994). It was also studied that Furadan 3G (carbofuran) application (37 kg/ha) in district Faisalabad. The results showed that a single application 90 days after the sowing of sugarcane effectively controlled sugarcane borers and also increased the sugarcane cane yield (Halimie *et al.,* 1994). Similarly seven granular insecticides were also applied against the sugarcane borer. From the results it was obtained that Furadan 3G and Desyston showed very good results. It was also noted that 0.4 kg monocrotophos was used against *Chilo infuscatellus* in variety CO-62175. The results showed that the lowest dead hearts percentage was 9.2% and highest cane yield was 110.7 t/ha while the economic threshold level (ETL) of pest was 15.46% (Marwat and Khalid, 1985; Mishra *et al.,* 1998).

Studied conducted by Talpur and Qureshi (2002) to asses the chemical effect of insecticides at Tandojam, Pakistan during 1999-2000. The insecticides Furadan 3G (carbofuran) @ 12 kg/ac, Basudin 10G (diazinon) @ 9 kg/ac, Padan 4G (cartap) @ 9 kg/ac and Thimet 5G (phorate) @ 10 kg/ac. From the results it was concludes that infestation percentage was minimum of stem borer after 10, 15 and 30 days before and after treatments. As result, increased the cane yield over check plot. It was also reported that Furadan gave very good results to control the stem borer infestation as compared to the other insecticides. Bessin *et al*. (1990) reported that control of sugarcane borer through insecticidal was the predominant factor which effect on plant injury. Madan *et al.* (1998) evaluated Chlorpyrifos 20 EC, Heptachlor 20 EC, Chlordane 20 EC, Sevidol 4 G and quinalphos 5 G applied at 1.25 kg a.i/ha for the control of stem borer *(Chilo infuscatellus)* on sugarcane during I990-92. From the Results it was concluded that Heptachlor and Chlorpyriphos very effective against stem borer. In another experiment different insecticides were used during 1985-87 in Pakistan. From the results it was found that the use of insecticides at initial stages gave best results and reduced the infestation from 4.48 to 3.63%.The infestation was high from 10.10 to 9.75% during 1986-1987 (Halimie *et al.,* 1989).

2.5 Biological Control:

The *Trichogramma* was reared at 6, 9, 12, 15 and 24°C for 8 weeks. At 15°C, more than 80% emergence was recorded in two weeks. At 6°C of storage percent emergence declined. Rate of parasitism in stored *Trichogramma,* was similar to that of the control after 2 to 4 weeks of storage at 9 °C and 12 °C, but the parasitization decrease with an increase in storage for more than 4 weeks (Pitcher *et al.,* 2002). The pesticides negatively affect on the natural enemies of sugarcane pest which increased the population of stem borer *Chilo infuscatellus* and root borer, *Emnmalocera depressella* (Muhammad and Mohyudin., 1987). The 150000 *Trichogramma chilonis* per hectare were released against the stalk borer *Chilo sacchariphagus* on sugarcane in Southern Asia and Southern Africa. The eggs were released in two places Savannah and Sainte-Marie and their results were compared with un-treated plots. The percentage of infestation was 45% in untreated plots less than the controls at Savannah and 35% at Sainte-Marie (Soula *et al.,* 2002). Similarly five treatments of *Trichogramma chilonis* were used. The treatment having 60,000 eggs of the parasitized per acre, showed significant result causing 83% reduction of *Chilo infuscatellus*. The population of *Chilo infuscatellus* showed a negative correlation with an increase in number of eggs which indicated that it can successfully used to control stem borer (Rafique *et al.,* 2007).

Studies was conducted by (Zia *et al.,* 2007) the use of biocontrol through artificial rearing of *Trichogramma chilonis* was started from 1999 and for *Chrysoperla carnea* it was started from 2002. From the results it was concluded that the infestation of borers was 11.65% under unreleased area and 2.74% under released area of *Trichogramma chilonis* and it was also noted that 80% eggs of *Pyrilla perpusilla* were predated by *Chrsoperla carnea* larvae under controlled conditions. From the results it was proved that the efficiency of biocontrol improved with integrated management techniques by using resistant varieties, trash blanketing of ratoon crop, balanced fertigation, early harvesting, pest-free seed cane and field monitoring. It was also reported that the effect of aerial spray and pesticides application was not effective against stem borer in sugarcane crop and it also adversely affect natural enemies of sugarcane insect pests, resulting in high population of stem borer *Chilo infuscatellus* and root borer, *Emnmalocera depressel* (Jan and Mohyuddin, 1987; Muhammad *et al.,* 1987). Studies that infestation was

reduced 52.04 % during 2000 and 60.03% during 2001. The damage ranged from 3.9 to 10.5% in treated and 9.6 to 18.6% in untreated plots. The internodes damaged reduction due to *Trichogramma* treated ranged from 28.6 59.7% (Mustafa *et al.*, 2006).

Ashraf *et al.* (1993) studied that the effect of inundative releases of *Trichograma chilonis* against the sugarcane borers during 1989-92 in Pakistan, on the sugarcane varieties L-116 and BL-4. The *Trichogramma* eggs were released at the rate of 8000-10000 parasitoids/acre during the entire growth period from April to October every year. The results showed that infestation was very low where the cards were installed. The variety BL-4 showed the infestation from 4.2 to 6.8% in treated plots and 15.70 to 24.60% in untreated plots. The variety L-116 showed the infestation from 3.8 to 6.1% in treated plots and 16.9 to 20.9% in untreated plots. Similarly in this experiment *Trichogramma chlonis,* released against *Chilo sacchariphagus* at Tamil Nadu, India. They reported that the used of parasitoid best release techniques showed higher percentage emergence of as compared to other conventional techniques (Rajendran and Hanifa., 1996). It was studied that large scale filed demonstration using *Trichogramma chilonis* against stalk borer in Punjab, India during 2000-2001. The *Trichogramma chilonis* was released @50000 per acre at 10 days interval from July to October. In term of borer infestation the damaged was 52.04% during 2000 and 60.03% during 2001 (Shenhmar *et al*., 2003).

The development and parasitization of two egg parasitoids *Trichogramma Chilonis* and *Trichogramma bactrae* were compared at different temperatures under laboratory conditions. Their development from egg to the adult emergence, lengthened at 15°C followed by at 20°C and 25°C for both cases. The maximum adult appearance was recorded at 25°C and the lowest at 35°C. For all life parameters of both parasitoids were favorable at 25°C. Similarly it was also studied that the rearing temperature for *Trichogramma chilonis* was 20, 25, 28, 31, 35 and 40^{o}C in the incubators. Biological parameters of parasitoids, *T. chilonis* such as parasitism (95.6%), developmental period (7.3 days), emergence (98.0%) and adult longevity (9.0 days) at 28^{o}C followed by at 25^{o}C (92.8%, 8.3 days, 96.2%, and 10.0 days, respectively). The minimum temperatures were evaluated as 20 and 35^{o}C with prolonged and reduced developmental period, respectively. The rearing at 40^{o}C did not

support the survival of parasitoids. From the results it was concluded that 28^{o}C temperature is very favorable for rearing of parasitoid (Hamid *et al.*, 2008; Sajad *et al.*, 2009).

2.6 Cultural and Mechanical Control:

Anwar *et al.* (2004) suggested that, the use for moth's collection, and cutting 2-3 unripend internodes along with tops infested with borer, pulling out of dead hearts and killing of the larvae of borers with iron bars poisoned with insecticides. It was suggested that effect of trash mulching on sugarcane crop against the stem borer *Chilo Infuscatellus* was very effective. The borer population was significantly suppressed in plots treated as trash mulching compared with trash burnt plots. This was because of the parasitoid activities in trash mulching plots. They reported that sugarcane yield was significantly increased in trash mulching plots (Makhdom *et al.*, 2001). Similarly hand collection of egg masses and their destruction before the formation of node reduce the pest population (Subramanian and Lyer; 1921; Flecher, 1919; Gupta and Avasthy 1954; Athwale, 1953). In this experiments intercropping of pulses with main crop of sugarcane reduce the damage the later by *Chilo infuscatellus.* Green gram was the mot effective reducing infestation by a maximum of 51% followed by black ram 31% and soybean 18% (Ranjendran *et al*., 1998). Jena *et al.* (1997) conducted fields study in Orissa. India. They reported that sugarcane receiving cultural control practices i.e. burning of trash, removing plants residue and removing water shoots sustained lowest percentage attacked (8.23%) compared to untreated plots, where the infestation was 19.3%. The sugarcane infested parts should be cut and fed to cattle and strong earthing-up following as the best control measures for borer control in sugarcane. He further stated that egg clusters should be mechanically and crop should be harvested deeply to increase 10% cane yield (Hashmi, 1994).

Rana *et al*. (1992) studied that Furadan 3G and Curator 3G @ 12 Kg/acre applied as side dressing followed by earthling up not only reduce the average cane borer infestation to 3 and 3.11% but also increased the stripped cane yield up to 292.12 and 288.31 quintal per acre. Irshad and Shah (1982) recommended rouging of sugarcane dry tops affected by borers from July to October to control several generations of this pest.

2.7 Combined Control Measures (IPM):

The experiment was conducted to find out the effectiveness of different control methods and their combination during 2001-2003 at Mardan. From the results it was concluded that the combinations of all control reduced the borer infestation and increased the sugarcane yield as result low the infestation and high the sugarcane yield when all control methods applied in combination. Similarly in another experiments, IPM of sugarcane borers was conducted at Sugar Crops Research Institute, Mardan during 1994-98. The results showed that and 3 ratoon crops collectively showed that plots treated with cultural, mechanical and chemical control showed minimum infestation against stem borer 0.27% and against root borer 0.25% (Gul *et al.,* 2008; Jan *et al.,* 1999). The use of IPM approach and its different control methods like cultural practices such as, avoidance of water logging, trash mulching, light earthing up and balanced use of fertilizer reduce the pest population. The varieties with hard mid-rib, erect and narrow leaves are less infested by sugarcane top borer. The effect of insecticidal control, varietal resistance and multiple control tactics were also tested in pest management. They reported that insecticidal control was predominant and provide control up to 60% while varietal resistance suppressing the control 42-47%. The variety CP 65-357 reduced the infestation, while the relative contribution of varietal resistance and insecticidal use gave the best control of borer infestation. From the result it was concluded that greater yield was increased when insecticidal control was used with combination with arthropod without predation (Madan, 2001; Bessin *et al.,* 1990).

In this experiment, the trash mulching and chemical method were compared for the control of sugarcane stem borer. A Concentration of Endrin, Trichlorophos, Methamedaphos, Clorpyriphos, Chlorfenviphos, Monocrotophos and Phosalone were compared with the ash mulching in one experiment whereas granular formulations of trichlorphos, disulfaton, fensulfithion, phorate, Carbyral + Lindane and aldicarb were tested along with Endrin and trash mulching in another experiment. The results showed that trash mulching is effective as the other two applications of the best insecticides namely Endrin 20% or Carbyral + Lindane 4% for the control of pest (Subramanian *et al.,* 1997). It was reported that combination of different control like cultural control methods, frequent irrigation, trash mulching, earthing up and application of monocrotophos showed 2.7-2.8% against *Chilo infuscatellus* and

maximum sugarcane yield 15.04 to 16.05 tons/ha. The installation of *Trichogramma chilonis cards* and cultural control were equally successful to reduce the pest population. The earthing-up in May and June, detrashing cane and removing of shoots, applying fertilizers during pre monsoon season, were effective for the control of sugarcane stalk borer *Chilo auricillus* (Sharma *et al.*, 1997; Jena *e1 al.*, 1997). The six ecology based approaches in combination i.e. timing irrigation and urea application, mechanical removal of damaging stages of pests and crop residues, earthing-up, propping of cane stalks, librations of egg parasitoids and foliar nitrogen application in sugarcane in India against sugarcane borers. They reported that, commutative use of these tactics reduced insect pests damage and cost of pest control. Moreover yield of sugarcane was significantly increased up to 22-36% in the IPM treated plots (Saroj and Jaipal, 2000).

It was reported that (Jalali *et al.*, 2000) the use of different control combination like, cutting of attacked shoots, removal of dead hearts and spike thrust, application of trash mulch and application of Furadan 3G @ 29 kg/ha, BHC dust application on setts @ 12 kg /ha and application of thiodan 35 EC @ 2.5 lit./ha against sugarcane borer showed very good results. The trash mulching showed the very best results and reduced the infestation 9.61 % during I994-95 and 13.85% during 1995-96 and also increased the sugarcane yield 109.50 to 110.13 ton/hac. The experiment was conducted at sugarcane crop research Institute Mardan during 1994-1997 on IPM of sugarcane borers. He collectively used cultural, mechanical and chemical control methods. He found that 3 plants and 3 ratoon crop revealed that treated plots reduce the shoot, gurdaspur and root borer infestation. He concluded that the use of combination of IPM resulted lowest borers infestation and higher cane yield in both plant and ratoon crop. The integration of different controls, balanced fertilization, strong earthing-up, early harvesting, rouging of dry shoots, tops, application of Furadan showed very effective controlled against the sugarcane borers. It was also reported that rouging of dry tops was better method for the borers control in sugarcane but the integration of these controls was best in all aspects against the borers (Jan, 1993, 1995). The treatment schedule of different controls like trash mulching, frequent irrigation, earthing up and application of monocrotophos showed very low infestation from 2.7-3.8% by *Chilo infuscatellus* and high yield 15.4-16.5 tons/ha. The Biological control by using the *Trichogramma chilonis* and cultural control were equally effective to reduce the pest population and increasing sugarcane

yield. The Integrated control methods including mechanical, destruction of borer egg masses and infested plants and shaving of stubbles, releasing of egg parasitoid *Trichogramma* eggs after 15 days interval and chemical application of Furadan granules. From the results it was concluded that all controls reduced borer infestation and increased cane and sugar yield (Sharma *et al.,* 1997; Gul and Saeed, 2007). The IPM approach was also used against sugarcane borers. The results showed that release of egg parasite *Trichogramma chilonis @* 20000 eggs/acre and trash mulching between rows was successfully controlled the sugarcane borers. The minimum infestation was 5.00% in 2002 and 4.33% in 2003 and the plots where egg parasites were released 6.75% in 2002 and 6.40% in 2003 with 18.33 and 26.65% parasitism. In Check places maximum borer infestation was 11.33% in 2002 and 12.65% in 2003 with minimum parasitism 0.42 and 0.33%. The earthing-up in May- June, detrashing, removing shoots and applications of fertilizers during pre monsoon season, gave very good results against *C'hilo auricillus* in sugarcane crop. The use of integration of various control against the sugarcane stem borer *Chilo infuscatrllus* showed very good results (Zubir *et al.,* 2007; Jena *et al.,* 1997; Hashmi and Rahim, 1995).

Chapter-3

MATERIALS AND METHODS

The experiment was conducted in Southern Punjab highly affected sugarcane area, at Akram abad (Distt, Rahim Yar Khan) and University of Agriculture Faisalabad from February 2008 to November 2009. The climate is very hot in summer up to 50°C while winter is cold up to 22°C. The average rainfall is very low as compared to other areas of Punjab.

3.1 Preliminary screening of varieties against *Chilo infuscatellus*:

The experiments were conducted to screen out the resistant and susceptible varieties of sugarcane on the basis of stem borer infestation. Fifteen early and late maturing varieties of sugarcane Viz., US-676, US-133, US-312, SPF-234, US-1491, US-824, CPF-246, US-718, CPF-237, CP-77-400, US-162, NSG-555, BL-4, L-116 and US-394 were screen out during spring 2008.

Experiment was laid out in a Randomized Complete Block Design (RCBD) in the Southern Punjab in highly affected sugarcane borer's areas at Akramabad Distt, Rahim Yar Khan. The plot size was kept 5×10 m^2 and the experiment was repeated thrice. There were five rows in each plot for each variety. Middle three rows were selected for recording the data during preliminary screening. All the recommended agronomic practices (Hoeing, Earthing up, balance use of fertilizer and irrigations) were applied during the experimentation. The infestation was calculated on the basis of infested tillers from the preliminary screening. The observations were taken at weekly intervals. The number of total internodes and infested internodes were counted separately from each cane and the borer infestation percentage on the basis of internodes damage was calculated by the following formula.

$$\text{Borer infestation (\% age)} = \frac{\text{Number of infested internodes}}{\text{Number of total internodes}} \times 100$$

3.2 Final screening of varieties against *Chilo infuscatellus*:

After preliminary screening, base on the infestation nine varieties of sugarcane Viz., US-676, US-133, US-312, SPF-234, US-1491, US-824, CPF-246, US-718 and CPF-237

were selected during 2009. Various Physico-morphological, chemicals and qualitative factors were also studied. Data was collected after 15 days interval in both years on the basis of infestation.

3.3 Host Plant Susceptibility Indices (HPSI's):

The Plant Susceptibility indices were determined on the basis of percentage infestation of *Chilo infuscatellus,* on the selected varieties by using IBM compatible computer having a Microsoft Chart Package. It was also calculated by following formula;

$$\text{HPSI (\%)} = \frac{B - A}{B} \times 100$$

Where

A= Infestation of *C. infuscatellus* on individual varieties; and

B = Infestation of *C. infuscatellus* on all varieties, on an average basis.

3.4 Role of Abiotic Factors:

There abiotic factors were responsible for the infestation like Temperature, Humidity and rainfall. The data on 15 days interval of both years were collected and correlated with infestation. The coefficient of determination was also determined through Multiple Regression Models.

3.5 Method to Test the Mechanism of Resistance in Sugarcane:

3.5.1 Qualitative Factors:

3.5.1.1 Analysis of Sugar Cane:

Analysis of cane includes Brix%, POL%, CCS%, Sugar Recovery% and Fiber% was determined. On the basis of these qualitative factors, the maturity of a cane variety was decided. When a cane variety attains Brix (20%), POL (18%) and purity (80%) in any month from October to March, it will be considered matured.

3.5.1.2 Juice Extraction:

The representative cane sample consists of 8-10 numbers of canes which were passed through cane crusher to get juice. The extracted juice was collected into a plastic bucket.

3.5.1.3 Brix (%):

For the Brix determination juice 400-500 ml was taken. The Brix was recorded through Brix hydrometer calibrated at 200°C. If temperature of juice was above 200°C, then a correction factor is added into 47 the recorded Brix reading, if the temperature was below

20°C, then correction factor was subtracted. Hydrometer was dip to down movement into cylinder after twenty five minutes, after that juice temperature come at room temperature.

3.5.1.4 POL (%):

200ml of extracted juice was taken into flask and added 5 g basic lead acetate and shake it well. The juice was filtered into a volumetric flask through a filter paper and injected into 200mm polarimeter tube to record the POL reading. The POL reading was the measurement of the angle of rotation of dextrorotatory substances. Polarity worked on the principle that under certain standard conditions i.e. standard tube length, standard solution concentration and standard room temperature when a polarized light was passed through that sugar solution, then substances present rotate light at a definite angle. The measurement of that angle of rotation was POL reading. Calculations will be done by following formula by Payne (1968).

3.5.1.5 Commercial Cane Sugarcane (CCS):

The commercial cane sugar will be determined by following formula.

$$CCS\ (\%) = \frac{3P \quad (1- F = 5) - B \quad (1- F = 3)}{2 \qquad 100 \qquad 2 \qquad 100}$$

CCS = Commercial Cane Sugar

P = POL apparent sucrose

F = Fiber contents

B = Brix percentage

3.5.1.6 Fiber Contents:

Fiber contents were determined by collecting 12 canes, top internodes of three canes, and middle portion internodes of next three canes while lower internodes of remaining three canes were cut, separated, mixed and fed to the Jaffco cutter grinder. This instrument was not only cuts and grinds but also minces the internodes. 500 gram sample of this grinded bagass was weighed and pressed less than 2000 pound per square inches on a hydraulic press for a period of two minutes. Now the fresh fiber cake was prepared which weighed and dried in oven for hours at 1000^{o}C. Percentage fiber will be done by using formula (Payne, 1968).

$$\text{Percent fiber} = \frac{\text{Weight of dried sample}}{\text{Weight of sample + wt. Lost during preparation}} \times 100$$

3.5.1.7 Sugar Recovery:

It was calculated by multiplying CCS with a constant factor 0.94. Actually to convert brown sugar into white sugar; 6% white sugar was also lost so a constant factor used.

In Pakistan, sugar mills used Recovery formula to determine sugar recovery.

Recovery = B.H.E. × B.H.R. × POL% juice × Juice extraction 0.94 (Mathur, 1981).

Where

B.H .E = Boiling House Efficiency

B.H.R. = Boiling House Recovery i.e. B.H.R. = S (J-M)

J (S-M)

Here

S = Sucrose purity

J = Juice purity

M = Molasses purity

3.5.2 Physico-Morphic Factors:

3.5.2.1 Leaf Thickness:

Five plants will be selected randomly from each block. The leaves will be cut from the upper, middle and lower part of the cane and determined the leaf thickness with help of binocular microscope.

3.5.2.2 Leaf Area:

Ten plants from each block will be selected randomly. Three leaves one from top, middle and bottom portion of the sugarcane will be taken. Leaves area will be measured with help of LI-30000, a portable area meter.

3.5.2.3 Leaf Sheath Hairiness:

Select the five canes in each block randomly. Each leaf sheath will be examined from three different places by phase contrast stereo microscope; the number of hairs will be counted in one centimeter area.

3.5.2.4 Stalk Girth:

For stalk girth, ten cane samples from each block will be taken randomly. From three different places upper, middle and lower from each the sugarcane sample will be selected for stalk girth. The stalk girth will be measured with help of ordinary measuring tape in centimeters.

3.5.3 Studies for the Biochemical Plant Factors:

The various biochemical factors (Nitrogen, Carbohydrate, Moisture contents, Fat contents, Fiber contents, Manganese, Zinc, Ferrous, K, Ca and P were calculated in finally selected nine varieties. The method used for the determination of biochemical characters was taken from A.O.A.C. (1990). The methods were briefly described as under;

3.5.3.1 Sampling Procedure:

The samples were pretreated to destroy the organic matter, because technique used for the metal analysis atomic absorption spectrophotometer required organic matter free and transparent solution. For this purpose wet digestion is carried out.

The weight of 50 grams fresh green leaves from each variety from the central shoot of the plant was collected. The sample will be washed with distilled water in the laboratory and kept into open air under shade for three hours. These leaves will be oven dry at 75°C for 12 hours. The oven dry material will be cut into pieces and shredded in grinder. Weight the 2 gm powder from each variety in separate and treated with 5 ml concentrated nitric acid to oxidize the organic material. For the thermal agitation, the flask were placed on the hot plate and covered with crucible lids. The hot plate was set at 70-80°C and slightly boiling of the sample after 2-3 hours. The temperature of the hot plate was then raised to 150°C and then removed the crucible lids to evaporate the digestion mixture and stayed over night. Added 5 ml of concentrated sulphuric acid and 3-5 ml of hydrogen peroxide. All the digestion procedure was performed in the fume hood for the prevention of hazardous effects of nitric acid. Continue heating till complete decomposition of organic matter took place and clear and transparent solutions were obtained. The contents of flasks were cooled and then added 10 ml of deonized water, Then filter the solution twice through Whatman Filter paper # 42 and made up to volume 25 ml with deionized water

3.5.3.2 Total Minerals:

We will take 2 grams weigh dry leaf tissue powder from each sample and put into a Boron fused silica crucible. Now the sample will be burnt to ashes in Muffle furnace at 600°C for five hours. The dry matter will be weighed and again put into same temperature till it was completely burnt into white/grayish ashes to constant weight. The experiment repeated four times. The total minerals will be calculated by following formula (Ranganna, 1977).

A

$$\text{Total Minerals (\% age)} = \frac{\text{---------}}{B} \times 100$$

A= weight of the ash

B= weight of the dried leaves

3.5.3.3 Fat Contents:

Fat was determined by taking 50 grams of crushed, oven dried sample in thimble plugged with cotton using n-hexane as solvent in a Soxhlet apparatus and heating the flask containing solvent. The fat extraction in Soxhlet was done by adjusting 3 drops of n-hexane per second till complete drawing of fat from sample. Then the content of the receiving flask was transferred to a pre weighed Petri dish and dried till to constant weight was obtained. Fat will be calculated with help of following formula.

$$\text{Fat (\%)} = \frac{\text{Weight of fat in Sample (gram)}}{\text{Weight of sample (gram)}} \times 100$$

3.5.3.4 Moisture Content:

For the determination of moisture, 50% sample from each variety was taken in Petri dishes dried in hot air oven at 70°C for 24 hours, till constant weight. The moisture contents were calculated by the formula given as;

$$\text{Moisture \%} = \frac{\text{Moisture losses}}{\text{Weight of original sample}} \times 100$$

Moisture losses = Weight of original sample – Weight of oven dried sample

3.5.3.5 Carbohydrates:

Carbohydrate will be determined by following formula.

Carbohydrate (%) = 100- crude protein + fats% + crude fiber + ashes

3.5.3.6 Micro and Macro Nutrients:

3.5.3.6.1 Analysis of Samples and Standards:

For the analysis of minerals two methods are used. Atomic absorption spectroscopy and flame photometry. For the analysis of zinc, iron, magnesium atomic absorption spectrometer was used while for sodium, potassium and calcium used the flame photometer.

3.5.3.6.2 Atomic Absorption Spectrophotometer Analysis:

The analysis of samples of sugarcane varieties and standard for the minerals was carried out by atomic absorption spectrophotometer with air acetylene flame. For minerals profile Perkin Elmer analyst 300 atomic absorption spectrophotometer was used. Other parameters including lamp current and wave length was standard. Hallow cathode lamps of metal ions manufactured by perkin Elmer that provide narrow spectral lines of moderate intensity with air acetylene system were used. The solution containing metal ions was introduced into the flame through aspiration, the metals ions through dissociation converted into atomic vapors. Atomic vapors was not grounded state in which electronic arrangements stable however part of it absorbed thermal energy emitted from the fame and putting the excited state in which energy level was higher. When light beam irradiated from hallow cathode lamp, atomic vapours in base state absorbed only the spectrum where a wave length inherited to measure the element and sate changes to excited state. The amount of intensity from spectrum to be absorbed proportional to the number of atoms in the base state or concentration of the metal ions.

3.5.3.7 Nitrogen:

0.5 grams of dry leaf tissue powder from each sample will be taken to determine the nitrogen percentage in leaf tissue by Kjeldalh Method (Winkleman *et al.*, 1986).

Determination of Nitrogen

Principle:

The change of nitrogenous compounds of sample into ammonium sulphate by boiling with sulphuric acid, Successive decomposition of ammonium sulphate with fixed alkali (40% NaOH) and collection of ammonia in acid solution, was titrated against acid of known strength and the Nitrogen of the sample was calculateded.

Reagents:

N/10 H_2SO_4, 40% sodium hydroxide, distilled water, 2% boric acid methyl red indicator, digestion mixture (K_2SO_4, $CuSO_4$ and $FeSO_4$), sugarcane sample, commercial H_2SO_4, and ethanol.

Preparation of digestion Mixture:

K_2SO_4	90 parts
$FeSO_4$	3 parts
$CuSO_4$	7 parts

Digestion:

The 2 gram sample of dried leaves of sugarcane was taken and added 10 gram digestion mixture was added in the Kjeldhal digestion flask (500 ml). The 25-30 ml commercial H_2SO_4 was added and heated till a light green was obtained.

Dilution:

Digested contents were transferred to a 250 ml volumetric flask and the volume made upto the mark with distilled water.

Distillation:

The10 ml of the sample solution was taken in a micro Kjeldhal distillation apparatus flask and 10 ml 40 % NaOH solution was added. Another flask was taken which containing 10 ml of 4% NaOH solution and added one drop of methyl red as an indicator. The flask was heated to produce fumes of ammonia gas which were trapped in 4% boric acid solution. The end point was a yellow colour. After 2 minutes, the flask containing boric acid was removed and the steam removed.

Titration:

The boric acid solution was titrated with N/10 H_2SO_4, till a golden colour was appeared. The volume of acid used was recorded and the calculation proceeded.

Calculation:

N% = Volume of N/10 H_2SO_4used × 0.0014 × volume of sample dilution × 100

Wt. of sample × volume of sample solution used (10ml)

3.6 Chemical Control:

In order to asses the chemical control of sugarcane stem borer *(Chilo infuscattelus)* on sugarcane crop, an experiment was conducted in the southern Punjab which is severely infested with sugarcane borers at Akramabad Distt, Rahim Yar Khan.

Homogeneous sets of a standard commercial sugarcane variety US-718 was planted in rows at a 2.5 feet R × R and 1 foot P × P distance between set to set. The experiment was laid out in an RCBD and replicated thrice with a plot size of 5×10 m^2 with five treatments in each block.

Four insecticides viz, Furadan 3G Carbofuran @12 kg/acre, Thimet @5G Phorate @ 10 kg /acre, Padan 4G Cartap @ 10 kg/acre and Monomehypo @ 8kg/acre were applied with a check for comparison. Three dressing was made at one month of each.

One variety US-718 showing resistance responses was selected from the previous studies and grown in three sets. Record the observations on the percentage of each damage 15 shoot were selected randomly from each treatment in each replication.

Damaged canes were separated; holes were counted and calculate the damage percentage calculated according to the given formula.

$$\% \text{ Infestation} = \frac{\text{No. of damaged cane}}{\text{No. of healthy cane}} \times 100$$

The Pre treatment observations were recorded one day before each application of insecticide, while the post treatment observations were recorded 10, 20 and 30 days after each dressing of the insecticide. All the collected data was analyzed statistically by Tukey HSD test.

3.7 Biological Control:

3.7.1 Rearing of *Sitotroga cerealella*

First wash the wheat grains from the dust and debris and dry under sunlight for 1-2 days. Then we incubated the wheat at 120°C for 25-30 minutes in an incubator to kill the pathogens. The trays filled with 6-8 kg wheat and 3-4 grams of *Sitotroga* eggs cover with muslin cloth using plastic rubber and kept at temperature of 28-32°C and a relative humidity 75±5% in the laboratory up to 25-28 days. The adults on emergence were collected with sieve at their bottom and kept in plates. The eggs collected in plates, within 24 hours, cleaned with 80 unit mesh sieve and now used for *Trichogramma* culture.

3.7.2 Rearing of *Trichogramma chilonis*

Fresh eggs of *Sitotroga* were put into a small vial cover with a sieve and spread on gummed card sheet, to attach them with it. Each sheet was contain four cards, each card containing about 500-600 *Sitotroga* eggs. 15-20 of such sheets were kept in plastic jars along with 4-5 sheets of parasitized cards of *Trichogramma* and kept at temperature of 25±1°C and a relative humidity 65±5% in the laboratory up to 6-7 days during the parasitoid eggs, first red and finally black in colour. The parasitoid cards were ready for use. In order to asses the biological control of sugarcane stem borer *(Chilo infuscatellus)* on the sugarcane crop, another experiment was conducted in the southern Punjab at Akramabad Distt. Rahim Yar Khan.

One variety US-718 showing resistance response was selected from the previous studies and sown in a Randomized Complete Block Designed (RCBD) with five treatmentsT_1, (40,000) parasitized cards/acre T_2, (48000 parasitized cards/acre) T_3, (60000 parasitized cards/ acre) T_4, (72000 parasitized cards/acre) and T_5, (control). Each treatment was replicated thrice in a single acre. Prepared parasitized eggs of *Trichogramma chilonis* were released in July and August 2009 when there was maximum attack of sugarcane stem borer. The parasitoids cards were installed on ventral surface of the leaves, in order to avoid the direct exposure of the sunlight. Infestation of the sugarcane stem borer was monitored after 10, 15 and 20 days on the basis of randomly selected sample from each treatment. Each treatment was consisting of five tillers of each experiment and the number of damaged plants by *Chilo infuscatellus as well as* the percentage of its infestation was calculated, as follows.

$$\% \text{ Infestation} = \frac{\text{Damaged tillers}}{\text{Total tillers}} \times 100$$

The percentage reduction in the stem borer infesting by installing *Trichogramma chilonis* was determined by the following formula.

$$\frac{\text{Damaged tillers in control plot} - \text{damaged tillers in treated plot}}{\text{Total tillers in control plot}} \times 100$$

The performance of the biological control agent *Trichogramma chilonis* was evaluated means of the sugarcane stem borer infestation and compared with that of the control plot. The data obtained was analyzed statistically by using Tukey HSD test.

3.8 Cultural and Mechanical Control:

This experiment as already explained, was conducted in southern Punjab areas at Akramalabad Distt, Rahim Yar Khan.

One variety US-718 showing resistance response was selected and grown in three sets. The lay out system was again RCBD with six treatments, having three repeats each block was kept 5×10 $m^{2.}$

T_1 = Trash Mulching

T_2 = Detrashing

T_3 = Propping

T_4 = Eggs Collecting

T_5 = Light Traps

T_6 = Control

Note: Detrashing is the removal of unwanted leaves from the cane, Propping is to tie the sugarcane stalks to save it from the lodging while the data on the percentage of cane damage at maturity will be recorded and analyzed statistically.

3.9 Integration of Various Control Methods:

This is experiment was conducted at Akramabad Distt, Rahim Yar Khan. One variety Us-718 showing resistance was selected and grown in three sets. The layout was RCBD with ten treatments and three replications. Each plot was kept 5×10 m^2.

T_1 = *Trichogramma* cards + Detrashing

T_2 = *Trichogramma* cards + Chemical control

T_3 = *Trichogramma* cards + Light Traps

T_4 = Detrashing + Chemical control

T_5 = Detrashing + light traps

T_6 = *Trichogramma* cards + Detrashing + Chemical control

T_7 = *Trichogramma* cards + Detrashing + Light traps

T_8 = *Trichogramma* cards + Chemical control + Light traps

T_9 = Chemical control + Light trap + Detrashing

T_{10} = Control

The results were obtained by assessing the damage caused by the borers from five randomly selected spots an interval at 15 days. The data on the percentage cane damage at maturity were recorded and analyzed statically in an appropriate way, the treatment means, were compared by means of Tukey HSD test at P= 0.05

Chapter-4

RESULTS

4.1 Preliminary Screening of Various Sugarcane Varieties:

The study was conducted to screen out fifteen varieties of sugarcane for their resistance/susceptible response base on the percentage infestation against the sugarcane stem borer *Chilo infuscatellus* during 2008. The results are described as under.

4.2 Screening of Varieties Base on the Infestation (%):

The data regarding base on the pest infestation on the various varieties of sugarcane against the stem borer infestation at various dates of observations are given in Table 1a. The analysis of variance of data regarding infestation caused by sugarcane stem borer showed significant difference among the varieties as the dates of observation. The means are compared by the Tukey HSD test (P=0.05). It is evident from the results that the variety US-394 showed maximum pest infestation 21.90% and was at par with NSG-555 and 21.60% which significantly different from other varieties BL-4, US-162, US-394, L-116 and CP-77-400 with infestation 20.73%, 20.38%, 19.64%, and 19.51%. The variety US-718 showed minimum infestation 15.49% after US-133 and US-676 with 15.59 and 16.46%. The variety CPF-237 showed 17.81% which significantly different from US-312, US-1491, US-824 and CPF-246 with 17.15, 17.12, 17.08 and 16.95% respectively.

4.3 Infestation Fluctuation at Various Dates of Observation During 2008:

The analysis of variance showed significance differences among the dates of observation. The means were compared with Tukey HSD test (P=0.05). The maximum infestation was recorded on August 30 during 2008 but the tremendous decrease was observed on September 15. The minimum infestation was recorded on April 15 during 2008.

Table-1 Analysis of variance table for infestation during year 2008

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	8.337	8.72
Date	13	2373.554	2483.38**
Variety	14	192.141	201.03**
Date x Variety	182	3.931	4.11**
Error	418	0.956	

** = Highly significant (P<0.01)

Table-1a The mean comparison of data regarding leaf infestation percentage caused by sugarcane stem borer on different varieties of sugarcane at different dates of observation during 2008

Variety	Mean
US-676	16.46 F
US-133	15.59 G
US-312	17.15 E
SPF-234	16.94 E
US-1491	17.12 E
US-824	17.08 E
CPF-246	16.95 E
US-718	15.49 G
CPF-237	17.81 D
CP-77-400	19.51 C
US-162	20.38 B
NSG-555	21.60 A
BL-4	20.73 B
L-116	19.64 C
US-394	21.90 A

Table-1b **The mean comparison of data regarding leaf infestation percentage caused by sugarcane stem borer on different dates of observation during 2008.**

Date	Mean
15-04-2008	07.79 M
30-04-2008	09.97 L
15-05-2008	12.25 K
30-05-2008	14.62 I
15-06-2008	17.20 H
30-06-2008	19.95 F
15-07-2008	23.28 E
30-07-2008	25.87 C
15-08-2008	28.24 B
30-08-2008	30.25 A
15-09-2008	23.81 D
30-09-2008	19.47 G
15-10-2008	13.74 J
30-10-2008	09.61 L

4.3 Final Screening of Varieties of Sugarcane:

Base on the data of stem borer infestation during 2008, in preliminary screening three varieties (US-718, US-312 and CPF-246) showed resistant and three moderate resistant (US-133, US-676 and US-1491) and three susceptible varieties (CPF-237, US-824 and SPF-234) were selected for final screening during 2009. The Bio-chemical plant factors of these varieties were also study to determine the role in mechanism of resistance in these varieties against sugarcane stem borer. The effect of various qualitative and abiotic factors on sugarcane was also investigated for final screening during 2009.

4.4 Screening of Varieties on the Basis of Infestation (%)

The data regarding to infestation of selected varieties of sugarcane stem borer during 2009 are given in Table-2a. The results showed significant difference and the means were compared with Tukey HSD test at (P=0.05). The minimum infestation was recorded in US-718 with 14.44%. The maximum infestation was recorded in CPF-237 with 15.95% followed by SPF-234 and US-824 with 15.87 and 15.78%. The varieties US-133, US-676 and US-1491 showed intermediate response with 15.69, 15/35 and 15%. The variety CPF-246 and US-312 showed significantly different response from other with 14.82 and 14.69%.

4.5 Infestation Fluctuation at Various Dates of Observation During 2009

The analysis of variance showed significance differences among the dates of observation. The means were compared with Tukey HSD test (P=0.05). The maximum infestation was recorded on May 30 during 2009 but the tremendous decrease was observed on June 15. The minimum infestation was recorded on August 30 during 2009.

Table-2 Analysis of variance table for infestation during 2009

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	2.627	3.6266
Date	13	1033.951	1427.3197**
Variety	8	13.461	18.5826**
Date x Variety	104	1.767	2.4391**
Error	250	0.724	

** = Highly significant (P<0.01)

Table-2a The mean comparison of data regarding leaf infestation percentage caused by sugarcane stem borer on different varieties of sugarcane at different dates of observation during 2009

Variety	Mean
US-676	15.35 BC
US-133	15.69 AB
US-312	14.69 DE
SPF-234	15.87 A
US-1491	15.00 CD
US-824	15.78 A
CPF-246	14.82 D
US-718	14.44 E
CPF-237	15.95 A

Table-2b **The mean comparison of data regarding leaf infestation percentage caused by sugarcane stem borer on different dates of observation during 2009**

Date	Mean
15-4-2009	14.18 F
30-4-2009	19.45 D
15-5-2009	20.08 C
30-5-2009	22.65 A
15-6-2009	21.16 B
30-6-2009	20.89 B
15-7-2009	16.76 E
30-7-2009	12.77 G
15-8-2009	10.36 H
30-8-2009	5.62 L
15-9-2009	6.67 K
30-9-2009	8.55 J
15-10-2009	9.45 I
30-10-2009	14.57 F

4.6 Host Plant Susceptibility Indices (HPSIs):

HPSIs were calculated among varieties based on the infestation of sugarcane stem borer with the objective to find the role of individual varieties towards susceptibility among the varieties under study for the years 2008-09 and on cumulative basis. The results are described as under;

4.6.1 Host Plant Susceptibility Indices (HPSIs) During 2008:

The HPSIs, base on the infestation of different varieties of sugarcane during 2008 are shown in Fig-1.The results revealed that varieties CPF-237 showed maximum HPSIs (13%) followed by US-676 with HPSIs 12%. The minimum HPSIs were determined by varieties US-718 and US-133 with 10%. The other varieties each had 11% HPSIs and proved to be intermediate.

4.6.2 Host Plant Susceptibility Indices (HPSIs) During 2009:

The HPSIs, base on the infestation on different varieties of sugarcane during 2009 are shown in Fig-2.The results revealed that variety SPF-234 and CPF-237 showed maximum HPSIs (12%). The minimum HPSIs were observed in variety US-718 (10%). The other varieties showed intermediate HPSIs with (11%).

4.6.3 Host Plant Susceptibility Indices on Cumulatively During 2008-09:

The results pertaining to HPSIs on cumulative basis for both the study years based on infestation on different varieties of sugarcane are presented in Fig-3. It is evident from the results that CPF-237 showed maximum HPSI i.e. 13% and proved susceptible whereas all the other varieties showed equal response each with 11% HPSIs. The variety US-718 showed minimum HPSIs (10%). From these results it was concluded that most of the varieties of sugarcane under study showed equal response towards population stem borer except CPF-237 which had maximum HPSI i.e. 13%.

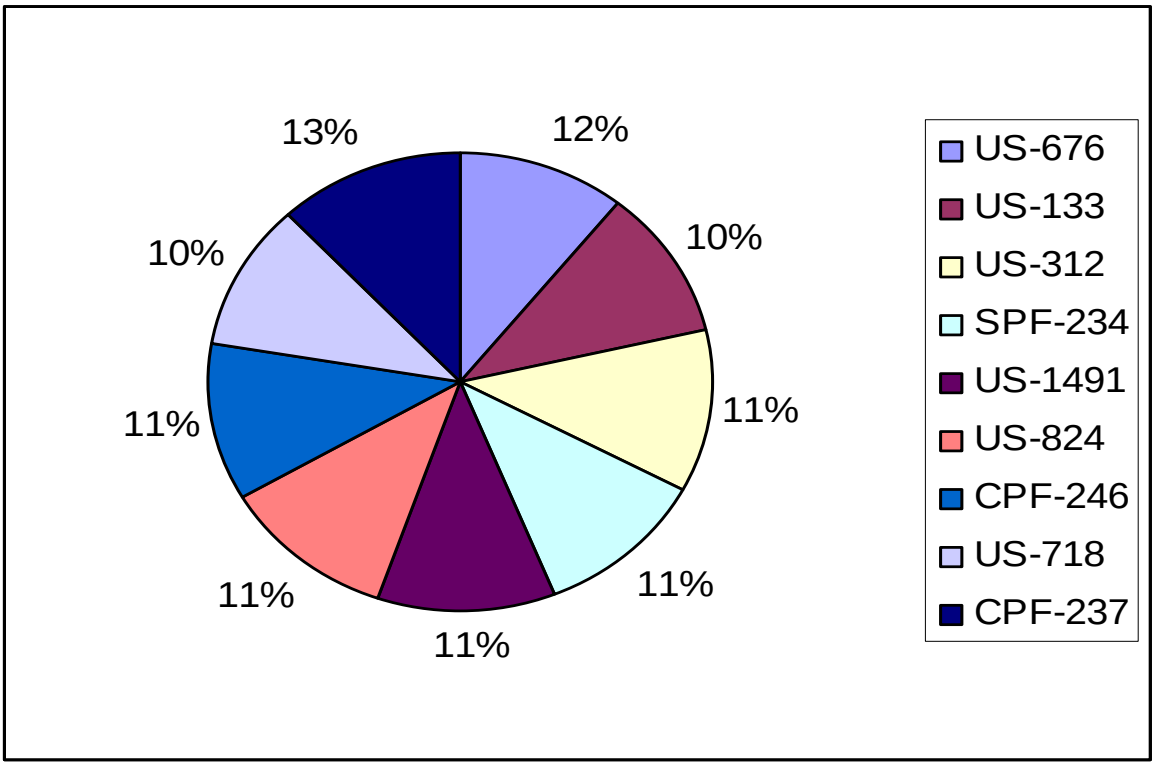


Fig-1 HPSIs (%) in various varieties of sugarcane on the basis infestation caused by *Chilo infuscatellus* during 2008

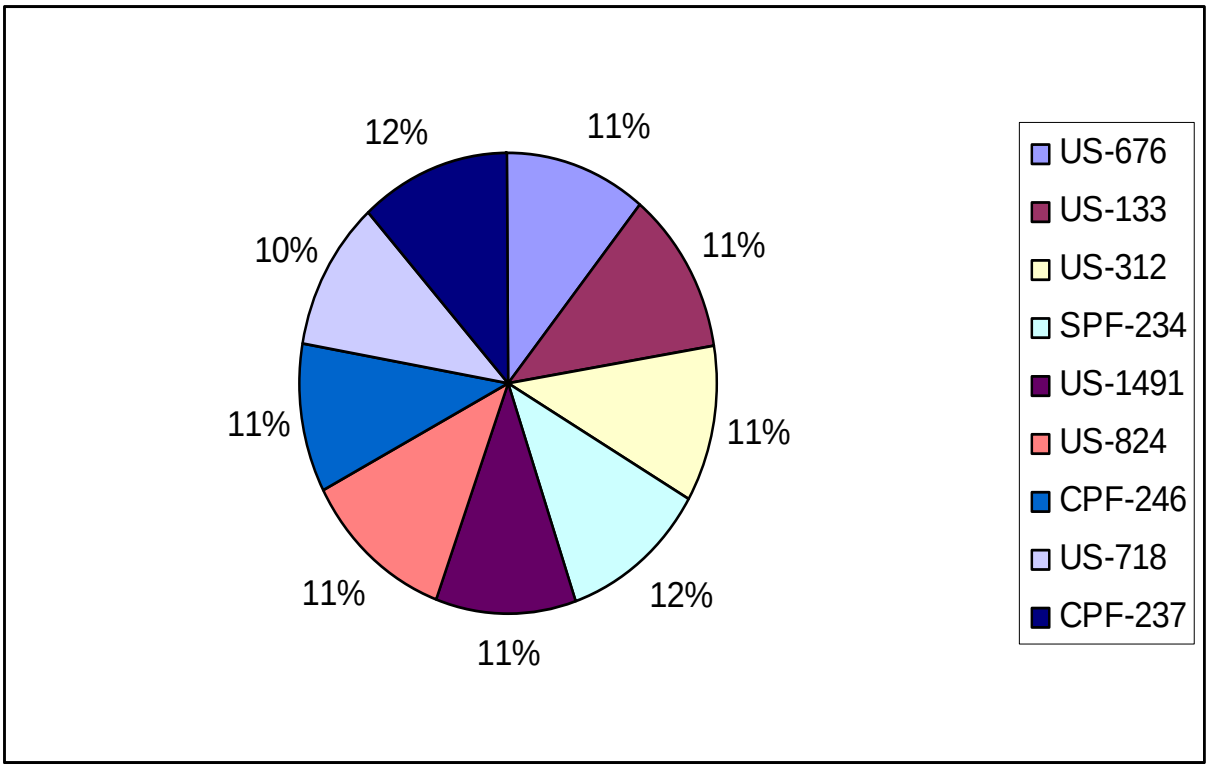


Fig-2 **HPSIs (%) in various varieties of sugarcane on the basis infestation caused by *Chilo infuscatellus* during 2009**

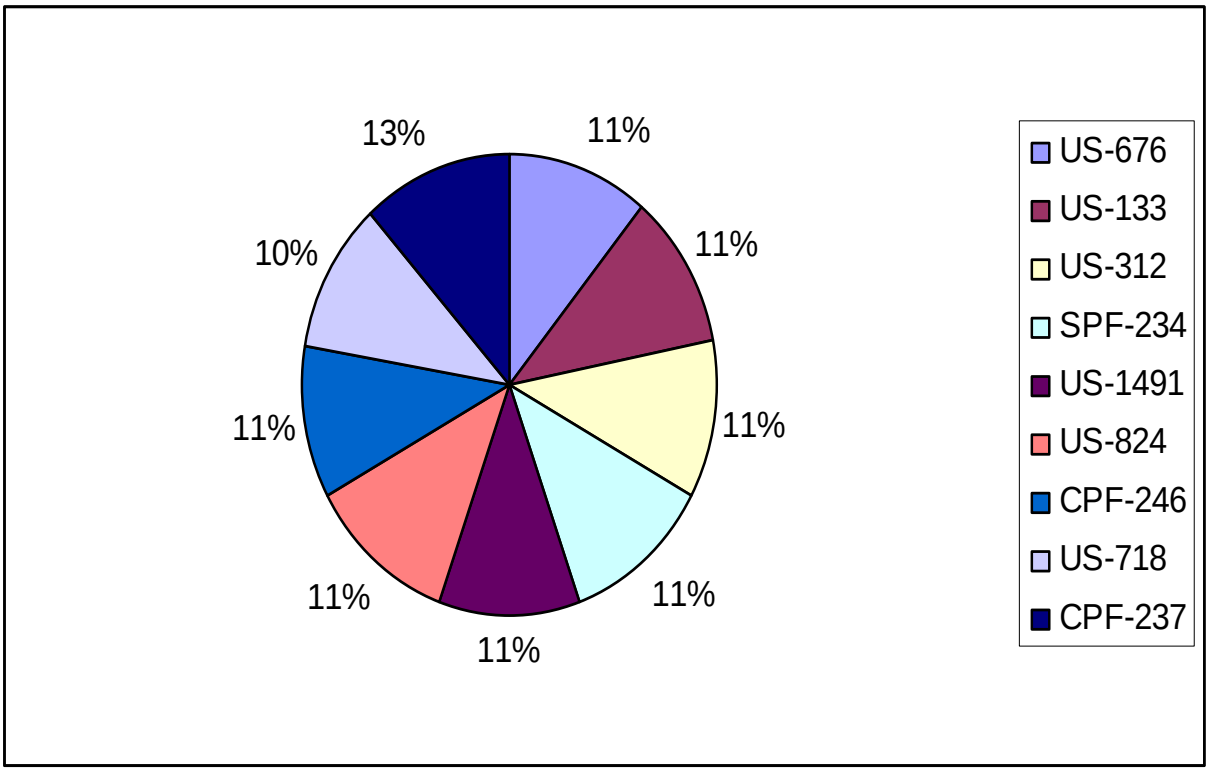


Fig-3 **HPSIs (%) in various varieties of sugarcane on the basis infestation caused by *Chilo infuscatellus* during 2008-2009**

4.6.4 Role of Weather Factors on the Pest Infestation:

The study was conducted to find out the effect of Temperature, Relative Humidity and Rainfall on the pest infestation during 2008-09. The data was subjected to simple correlation and multiple linear regression analysis for two years separate and collectively. Coefficient of determination values were also determined to see their role in percentage on the population fluctuation of the pest under study. The results are described as under;

4.6.5 Effect of Abiotic Factors on Infestation of Sugarcane Stem Borer During 2008:

It is evident from the results (Table 3) that during 2008, maximum and minimum temperature showed positive but non significant with r-value 0.049 and 0440% while Relative humidity showed positive and significant correlation with infestation with r-value 0.637. The rainfall showed positive and highly significant correlation with infestation with r-value 0.770. The regression equation was fitted to be best. The contribution in fluctuating the pest infestation was 79.0 % when all the abiotic factors regressed together.

4.6.6 Effect of Abiotic Factors on Infestation of Sugarcane Stem Borer During 2009:

During 2009, maximum, minimum temperature and relative humidity showed positive but non significant correlation with sugarcane stem borer infestation with r-value 0.410, 0.523 and 0.520% respectively and rainfall showed positive and highly significant effect on the infestation with r-0.781. The regression equation was again fitted to be best. The contribution of abiotic factors on the fluctuation of pest infestation during 2009 was calculated 97.9%.

4.6.7 Cumulative Effect of Abiotic Factors on Infestation of Sugarcane Stem Borer During 2008-09

The results regarding correlation coefficient between weather factors and infestation of sugarcane stem borer during both years cumulatively revealed that maximum temperature showed negative and non significant correlation with infestation -0.064% while minimum temperature showed positive and significant relation with infestation with r-value 0.406. The relative humidity and rainfall showed positive and highly significant correlation with infestation with r value 0.529 and 0.765%. The regression equation was again fitted to best. The cumulative effect of abiotic factors in fluctuating pest infestation was recorded 70.4%.

Table-3 Correlation matrix along with regression equation and coefficient of determination value among abiotic factors and infestation during year 2008

Character	Infestation (%)	Max. Temp. (°C)	Min. Temp. (°C)	Relative Humidity (%)	Rainfall (mm)
Infestation	1.000				
Temp. Maximum	0.049	1.000			
Temp. Minimum	0.440	0.498	1.000		
Relative Humidity (%)	0.637*	-0.394	0.065	1.000	
Rainfall (mm)	0.770**	-0.023	0.222	0.446	1.000

* = Significant (P<0.05)

** = Highly significant (P<0.01)

Regression Equation

$$Y = - 24.0 + 0.176\ X_1 + 0.567\ X_2 + 0.295\ X_3 + 0.227\ X_4$$

Where

Y = Infestation (%)

X_1 = Maximum temperature (°C)

X_2 = Minimum temperature (°C)

X_3 = Relative humidity (%)

X_4 = Rainfall (mm)

Coefficient of determination (R^2) = 79.0%

Table-4 Correlation matrix along with regression equation and coefficient of determination value among abiotic factors and infestation during year 2009

Character	Infestation (%)	Max. Temp. (°C)	Min. Temp. (°C)	Relative Humidity (%)	Rainfall (mm)
Infestation	1.000				
Temp. Maximum	0.410	1.000			
Temp. Minimum	0.523	-0.046	1.000		
Relative Humidity (%)	0.520	-0.178	0.036	1.000	
Rainfall (mm)	0.781**	0.035	0.466	0.287	1.000

* = Significant (P<0.05)

** = Highly significant (P<0.01)

Regression Equation

$Y = - 13.5 + 2.89 X_1 + 0.489 X_2 + 0.209 X_3 + 0.258 X_4$

Where

Y = Infestation (%)

X_1 = Maximum temperature (°C)

X_2 = Minimum temperature (°C)

X_3 = Relative humidity (%)

X_4 = Rainfall (mm)

Coefficient of determination (R^2) = 97.9%

Table-5 Correlation matrix along with regression equation and coefficient of determination value among abiotic factors and infestation during year 2008 and year 2009

Character	Infestation (%)	Max. Temp. (°C)	Min. Temp. (°C)	Relative Humidity (%)	Rainfall (mm)
Infestation	1.000				
Temp. Maximum	-0.064	1.000			
Temp. Minimum	0.406*	0.522**	1.000		
Relative Humidity (%)	0.529**	-0.345	0.063	1.000	
Rainfall (mm)	0.765**	-0.0.79	0.301	0.347	1.000

* = Significant (P<0.05)

** = Highly significant (P<0.01)

Regression Equation

Y= - 6.0 - 0.059 X1+ 0.448 X2 + 0.170 X3 + 0.280 X4

Where

Y = Infestation (%)

X_1 = Maximum temperature (°C)

X_2 = Minimum temperature (°C)

X_3 = Relative humidity (%)

X_4 = Rainfall (mm)

Coefficient of determination (R^2) = 70.4%

4.7 Role of Qualitative Factors on the Stem Borer Infestation:

The data regarding qualitative factors were subjected to correlation coefficient values and multiple linear regression models to find out the impact of these factors on the infestation. The results are presented as under;

4.7.1 Correlation Coefficient between Qualitative Factors and Stem Borer Infestation:

Various qualitative factors were correlated with the pest infestation and the results are given in Table 6. It is evident from the results that Brix and POL percentage showed negative and significant correlation with pest infestation with r-value -0.650 and -0.683 while the fiber and CCS showed negative and non significant correlation with stem borer infestation with r-value 0.291 and 0.643. From the results it is concluded that that Brix and POL were the important factors which showed significant effect on the infestation.

The results pertaining to multiple linear regression analysis of variance between infestations of stem borer and qualitative factors through steps are presented in Table 7.

The result showed that fiber contents contributed minimum 8.5% towards the infestation while the Brix contribute 44.6%. The POL contribution was recorded 58.5% when POL was added. The 100 R^2 value was reached to 61.4% when all the factors computed together. From these results it concluded that fiber contents showed negligible impact while other qualitative factors showed maximum per unit change in population fluctuation of the pest infestation.

4.7.2 Role of Physico-Morphic Factors on the Stem Borer Infestation:

The data regarding qualitative factors were subjected to correlation coefficient values and multiple linear regression models to find out the impact of these factors on the infestation. The results are presented as under.

Various physico-morphic factors were correlated with the pest infestation and the results are given in Table 8. It is evident from the results that plant girth, leaf area, leaf sheath hairiness and leaf thickness showed negative and non significant correlation with pest infestation with r-value 0.139, 0.181, 0.287 and 0.381 respectively.

The results pertaining to multiple linear regression analysis of variance between the physico-morphic plant factors and infestation through steps are presented in Table 9.

Plant girth contributes 2% while leaf area contributes 6%. The contribution of leaf sheath hairiness and leaf thickness 35.6% in fluctuating the pest infestation. From the results

it was concluded that plant girth and leaf area showed negligible impact on the pest infestation while leaf sheath hairiness and leaf thickness was important factors which showed maximum per unit change in population fluctuation of the pest.

4.7.3 Role of Chemical plant Factors on the Stem Borer Infestation:

The data regarding chemical factors were subjected to correlation coefficient values and multiple linear regression models to find out the impact of these factors on the infestation. The results are presented as under.

Various chemical plant factors were correlated with the pest infestation and the results are given in Table 10. It is evident from the results that impact of moisture, Total Minerals, Potassium, Calcium, Ferrous and Fat was negative and non significant. All other factors Carbohydrate, Nitrogen, Phosphorous, Magnesium, Copper, Manganese and zinc showed positive and non significant impact on pest infestation.

The results pertaining to multiple linear regression analysis of variance between the chemical plant factors and infestation through steps are presented in Table 11. The moisture contributes in pest infestation 5.7% followed by total minerals and Carbohydrate with 19.5 and 27%. The Nitrogen percentage contributes in pest infestation 33.5%. On the addition of phosphorous this value increased up to 50.7% followed by Potassium (57.9%) and Calcium (62%).

Table-6 Correlation Between Infestation and Various Sugars Qualitative Factors

Factors	Correlation (r)
Fiber (%)	-0.291
Brix (%)	-0.650
POL (%)	-0.683*
CCS (%)	-0.643

Table-7 Regression Analysis for Sugar Qualitative Factors

Regression Equation	R^2
$Y = 18.9 - 0.275\ X_1$	0.085
$Y = 22.1 - 0.147\ X_1 - 0.223\ X2$	0.446
$Y = 13.4 - 0.073\ X_1 + 1.33\ X_2 - 1.38\ X_3$	0.585
$Y = 11.6 + 0.056\ X_1 + 1.52\ X_2 - 1.91\ X_3 + 0.434\ X_4$	0.614

Y = Infestation (%)

X_1 = Fiber

X_2 = Brix

X_3 = POL

X_4 = Commercial Cane Sugar (CCS)

R^2 = Coefficient of Determination

Table-8 Correlation Between Stem Borer Infestation and Various Physico-Morphological Plant Factors

Factors	Correlation (r)
Plant Girth	-0.139
Leaf Area	-0.181
Leaf sheath hairiness	-0.287
Leaf Thickness	-0.381

Table-9 Regression Analysis For Morphological Plant Factors

Regression Equation	R^2
$Y = 16.2 - 0.188\ X_1$	0.020
$Y = 17.4 - 0.248\ X_1 - 0.00223\ X2$	0.066
$Y = 22.1 - 0.510\ X_1 - 0.00621\ X_2 - 0.0240\ X_3$	0.356
$Y = 22.0 - 0.520\ X_1 - 0.00629\ X_2 - 0.0244\ X_3 + 0.3\ X_4$	0.356

Y = Infestation

X_1 = Plant Girth

X_2 = Leaf Area

X_3 = Leaf sheath hairiness

X_4 = Leaf Thickness

R^2 = Coefficient of Determination

Table-10 Correlation Between Infestation and Various Chemical Plant Factors

Factors	Correlation Coefficient Value (r)
Moisture (%)	-0.239
Total minerals (%)	-0.130
Carbohydrates (%)	0.288
Nitrogen (%)	0.335
Phosphorous (%)	0.144
Potassium (%)	-0.121
Calcium (%)	-0.209
Magnesium (%)	0.154
Copper (ppm)	0.328
Ferrous (ppm)	-0.170
Manganese (ppm)	0.608
Zinc (ppm)	0.638
Fat (%)	-0.095

Table-11 Regression Analysis For Chemical Plant Factors

Regression Equation	**R^2**
$Y = 72.7 - 0.73\ X_1$	0.057
$Y = 205 - 1.72\ X_1 - 7.58\ X_2$	0.195
$Y = 178 - 1.34\ X_1 - 8.76\ X_2 + 0.112\ X_3$	0.270
$Y = -70 + 1.23\ X_1 - 4.6\ X_2 + 0.216\ X_3 + 10.8\ X_4$	0.348
$Y = -246 + 3.10\ X_1 - 2.9\ X_2 + 0.270\ X_3 + 20.4\ X_4 + 14.3\ X_5$	0.507
$Y = -566 + 6.61\ X_1 + 1.2\ X_2 + 0.407\ X_3 + 31.3\ X_4 + 7.5\ X_5 - 9.7\ X_6$	0.579
$Y = -544 + 6.2\ X_1 + 3.3\ X_2 + 0.365\ X_3 + 30.7\ X_4 + 5.7\ X_5 - 12.0\ X_6 - 7.3\ X_7$	0.620

Y = Infestation

X_1 = Moisture

X_2 = Total Minerals

X_3 = Carbohydrate

X_4 = Nitrogen

X_5 = Phosphorous

X_6 = Potassium

X_7 = Calcium

R^2 = Coefficient of Determination

4.7.4. Qualitative Analysis:

4.7.4.1 Brix Contents (%):

Analysis of variance for the data regarding Brix percentage in various selected varieties of sugarcane indicated highly significant. The mean value in table 12a revealed maximum percentage of Brix in variety US-312 (23.43%) followed by US-718 and US-1491 with 23.33% and 23.06% which significantly different from all other. The variety CPF-246 showed 22.68 % Brix contents which are not differ from US-133 and CPF-237 with 22.50 and 22.34 %. The varieties SPF-234 showed minimum percentage of Brix contents 18.46% after US-824 and US-676 with Brix contents 21.41 and 21.04% respectively.

4.7.4.2 POL (%):

Differences were found to be highly significant, among the selected varieties, regarding the quantity of POL %. The means compared by Tukey HSD test (P=0.05) are given in Table 13a which revealed that POL percentage in US-312 and US-718 with 20.93% and 20.92% were comparatively higher and did not differ from one another. The varieties US-133, US-1491 and CPF-246 showed intermediate percentage with 19.83%, 20.16% and 19.93% respectively and significantly different from all other varieties. The variety SPF-234 revealed minimum POL percentage 15.27%. The varieties CPF-237, US-824 and US-676 contained 19.34%, 18.50% and 18.00% POL, respectively which differed significantly from one another as well as other varieties.

4.7.4.3 Commercial Cane Sugar (CCS):

It is evident from the results that difference was highly significant among varieties. The variety US-718 showed maximum percentage 15.84 followed by varieties US-312 and US-1491 with 15.66 and 15.30 percent which significantly from all other varieties. The variety SPF-234 showed minimum percentage of CCS 11.08 which significantly different from all other varieties. The varieties US-133, CPF-237 and CPF-246 revealed significantly different from all other varieties but did not differ from one another with CCS 14.99, 14.31 and 14.17% respectively. The varieties US-824 and US-676 showed the CCS percentage 13.66 and 13.18% which different from all other.

4.7.4.4 Fiber Contents (%):

The data pertaining fiber contents in selected varieties of sugarcane given in Table-15a. The means were compared by Tukey HSD test (P=0.05). The maximum fiber contents

were found in US-676 (13.68%) which did not differ from 13.60%, 13.52%, 13.47% and 13.45% fiber contents in CPF-246, CPF-237, US-312 and US-718 respectively. The variety US-1491 showed minimum percentage of fiber contents 11.99% which significantly different from all other varieties. The varieties US-133 US-824 and SPF-234 showed fiber contents percentage 12.74%, 12.64% and 12.59% which significantly different from other but did not differ from one another. So the conclusion is that the variety US-676 showed maximum fiber contents while US-1491 contains minimum.

4.7.4.5 Recovery (%):

The data regarding recovery percentage in different varieties were highly significant. The means were compared by Tukey HSD test (P=0.05). The maximum recovery percentage 11.74% was found in US-312 which did not differ from US-718, US-1491 and US-133 with 11.52%, 11.29% and 11.15% which significantly different from other varieties. The variety SPF-234 showed minimum percentage of recovery 8.12% which highly significantly different from other. The varieties CPF-246, CPF-237, US-676 and US-824 showed intermediate recovery percentage with 10.55%, 10.42%, 10.16% and 10.05% respectively.

4.7.4.6 Fat %:

Analysis of variance of data regarding fat % showed highly significant against selected varieties of sugarcane. The means were compared by HSD Tukey test (P=0.05). The maximum percentage of fat contents were recorded in variety SPF-234 (2.20%) followed by US-718, US-824 and Us-676 with 2.18%, 2.17% and 2.16% respectively which were similar to each other but significantly different from other varieties. The US-133, US-1491 and CPF-237 showed minimum percentage of fat contents which were similar but significantly different from other. The varieties US-312 and CPF-246 showed 2.12 and 2.06% fat contents.

4.7.4.7 Moisture Content (%):

Variations were found to be significant among varieties regarding moisture percentage in selected sugarcane varieties. The maximum percentage was recorded in US-312, 78.65% followed by 78.60 and 78.51% in varieties SPF-234 and US-824 which are significantly different from other. The variety US-133 showed minimum percentage of moisture 78.04% which highly significant from all other varieties, while the means of US-718, US-1491, US-676 and CPF-246 did not differ significantly and were 78.42%, 78.37%,

78.35% and 78.32%. The variety CPF-237 showed 78.26% moisture contents which were highly significant from all other varieties.

4.7.4.8 Carbohydrates (%):

It is evident from the results that difference was highly significant among the selected varieties regarding to the carbohydrate percentage. The means were compared by Tukey HSD test (P=0.05). The variety US-1491 showed minimum percentage of carbohydrate 47.57% after US-824 (48.42%) which significantly different from all other varieties. The US-133 showed maximum percentage of carbohydrates, 52.57% which did not differ significantly from CPF-237 with 52.34%. The varieties CPF-246, US-718, US-676 and US-312 showed carbohydrate percentage 51.12%, 50.32%, 49.55% and 49.46% which significantly different from other varieties.

Table-12 Analysis of Variance of the Data Regarding Brix (%) of Different Selected Varieties of Sugarcane

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	1.0675	1.49
Variety	8	7.3220	10.21**
Error	16	0.7172	

** = Highly significant (P<0.01)

Table-12a A Comparison of Means for the Data Regarding Brix (%) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	21.04±0.48
US-133	22.50±0.28
US-312	23.43±0.47
SPF-234	18.46±0.75
US-1491	23.06±0.10
US-824	21.41±0.74
CPF-246	22.68±0.34
US-718	23.33±0.27
CPF-237	22.34±0.65

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05).

Table-13 Analysis of Variance Table for POL (%)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.0464	0.10
Variety	8	9.4410	21.13**
Error	16	0.4468	

** = Highly significant (P<0.01)

Table-13a. A Comparison of Means for the Data Regarding POL (%) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	18.00±0.07 D
US-133	19.83±0.38 AB
US-312	20.93±0.34 A
SPF-234	15.27±0.30 E
US-1491	20.16±0.43 AB
US-824	18.50±0.34 CD
CPF-246	19.93±0.51 AB
US-718	20.92±0.31 A
CPF-237	19.34±0.44 BC

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05).

Table-14 Analysis of Variance Table for CCS

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.9523	2.84
Variety	8	6.6425	19.78**
Error	16	0.3358	

** = Highly significant (P<0.01)

Table-14a A Comparison of Means for the Data Regarding CCS (%) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	13.18±0.17 E
US-133	14.99±0.34 ABC
US-312	15.66±0.37 A
SPF-234	11.08±0.26 F
US-1491	15.30±0.53 AB
US-824	13.66±0.17 DE
CPF-246	14.17±0.64 CDE
US-718	15.84±0.28 A
CPF-237	14.31±0.27 BCD

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

Table-15 Analysis of Variance Table for Fiber (%)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.03009	0.67
Variety	8	1.07144	23.71**
Error	16	0.04518	

** = Highly significant (P<0.01)

Table-15a A Comparison of Means for the Data Regarding Fiber (%) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	13.68±0.08 A
US-133	12.74±0.10 B
US-312	13.47±0.14 A
SPF-234	12.59±0.16 B
US-1491	11.99±0.05 C
US-824	12.64±0.07 B
CPF-246	13.60±0.10 A
US-718	13.45±0.06 A
CPF-237	13.52±0.22 A

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

Table-16 Analysis of Variance Table for Recovery (%)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.0068	0.07
Variety	8	3.5941	37.98**
Error	16	0.0946	

** = Highly significant (P<0.01)

Table-16a A Comparison of Means for the Data Regarding Recovery (%) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	10.16±0.18 C
US-133	11.15±0.16 B
US-312	11.74±0.13 A
SPF-234	8.12±0.12 D
US-1491	11.29±0.14 AB
US-824	10.05±0.14 C
CPF-246	10.55±0.29 C
US-718	11.52±0.16 AB
CPF-237	10.42±0.14 C

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

Table-17 Analysis of Variance Table for Fat (%)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.00027	0.18
Variety	8	0.02321	15.74**
Error	16	0.00148	

** = Highly significant (P<0.01)

Table-17a A Comparison of Means for the Data Regarding Fat (%) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	2.16±0.009 AB
US-133	1.99±0.024 D
US-312	2.12±0.027 BC
SPF-234	2.20±0.022 A
US-1491	1.99±0.024 D
US-824	2.17±0.020 AB
CPF-246	2.06±0.023 CD
US-718	2.18±0.009 AB
CPF-237	2.00±0.023 D

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

Table-18 Analysis of Variance Table for Moisture Content (%)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.00348	0.34
Variety	8	0.10197	10.08**
Error	16	0.01012	

** = Highly significant (P<0.01)

Table-18a A Comparison of Means for the Data Regarding Moisture Content (%) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	78.35±0.037 CD
US-133	78.04±0.042 E
US-312	78.65±0.137 A
SPF-234	78.60±0.023 AB
US-1491	78.32±0.055 CD
US-824	78.51±0.018 ABC
CPF-246	78.37±0.035 CD
US-718	78.42±0.025 BCD
CPF-237	78.26±0.020 D

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

Table-19 Analysis of Variance Table for Carbohydrates (%)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.0463	0.35
Variety	8	8.2985	63.03**
Error	16	0.1317	

** = Highly significant (P<0.01)

Table-19a A Comparison of Means for the Data Regarding Carbohydrates (%) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	49.55±0.11 D
US-133	52.57±0.19 A
US-312	49.46±0.11 D
SPF-234	50.32±0.16 C
US-1491	47.57±0.22 F
US-824	48.42±0.24 E
CPF-246	51.12±0.40 B
US-718	50.32±0.09 C
CPF-237	52.34±0.09 A

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

4.7.5 Physico-Morphological Factors:

4.7.5.1 Leaf Area:

Analysis of variance for the data regarding leaf area in various selected varieties of sugarcane indicated highly significant. The mean value revealed that maximum leaf area in variety SPF-234 (466 cm^2) which did not differ from variety US-676 with 461 cm^2. The CPF-246 showed leaf area 414 cm^2 followed by US-718, US-1491 and US-312 with 394, 382 and 359 cm^2.The variety US-824 showed minimum leaf area 318 cm^2 after US-133 and CPF-237 with 337 and 323 cm^2. It concluded that variety SPF-234 showed maximum leaf area while US-824 minimum.

4.7.5.2 Leaf Sheath Hairiness:

The data regarding leaf sheath hairiness in different selected varieties of sugarcane is highly significant. The means were compared with HSD Tukey test (P=0.05). The maximum leaf sheath hairiness 102 cm^2 was recorded in CPF-246 which significantly different from other varieties followed by US-1491 and CPF-237 with 95 cm^2 which are similar to each other. The variety SPF-234 showed minimum leaf sheath hairiness 53 cm^2 which significantly different from all other followed by US-676 with 63 cm^2. The varieties US-133, US-718, US-824 and US-312 showed intermediate leaf sheath hairiness with 82, 81, 78 and 76 cm^2 respectively which significantly different from other but similar to each other.

4.7.5.3 Leaf Thickness:

Analysis of variance for the data regarding leaf area in various selected varieties of sugarcane indicated significantly different. The maximum leaf thickness was found in variety CPF-246 (0.660mm) which similar to varieties US-824, US-1491 and US-676 with 0.647, 0.637 and 0.627mm. The variety CPF-237 showed minimum leaf thickness 0.583 after SPF-234 with 0.597 which similar to each other but significantly different from other varieties. The varieties US-133, US-312 and US-718 showed similar to each other but significantly different from other varieties with 0.617, 0.617 and 0.613mm.

4.7.5.4 Plant Girth:

Analysis of variance of data regarding Brix contents in different sugarcane varieties' shows highly significant different. The means were compared by Tukey HSD test (P=0.05) which revealed that maximum plant girth 5.4 cm^2 in variety US-824 followed by US-1491, US-312 and US-676 with 5.43 cm^2, 5.23 cm^2 and 5.1 cm^2 which differed significantly from

all other varieties. The varieties US-718, US-133 and SPF-234 showed intermediate percentage 4.78 cm^2, 4.73 cm^2 and 4.56 cm^2 respectively which significantly different from other. The variety CPF-246 showed minimum plant girth percentage 4.37 cm^2 as compared to all other varieties followed by the varieties CPF-237 and SPF-234 with 4.44 cm^2 and 4.56 cm^2 respectively.

Table-20 Analysis of Variance Table for Leaf Area (cm^2)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	16.200	1.07
Variety	8	9251.100	611.86**
Error	16	15.100	

** = Highly significant (P<0.01)

Table-20a A Comparison of Means for the Data Regarding Leaf Area (cm^2) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	461.84±1.85 A
US-133	337.84±3.55 F
US-312	359.11±1.34 E
SPF-234	466.57±1.14 A
US-1491	382.99±1.82 D
US-824	318.50±3.45 G
CPF-246	414.99±1.27 B
US-718	394.45±1.97 C
CPF-237	323.31±2.43 G

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

Table-21 Analysis of Variance Table for Leaf Sheath Hairiness (cm^2)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	1.510	0.13
Variety	8	748.120	63.81**
Error	16	11.720	

** = Highly significant (P<0.01)

Table-21a A Comparison of Means for the Data Regarding Leaf Sheath Hairiness (cm^2) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	63.02±2.76 D
US-133	82.54±1.32 C
US-312	76.66±2.00 C
SPF-234	53.42±2.65 E
US-1491	95.25±1.74 B
US-824	77.76±1.75 C
CPF-246	102.42±1.11 A
US-718	81.57±1.89 C
CPF-237	95.73±0.69 B

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

Table-22 Analysis of Variance Table for Leaf Thickness (mm)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.00025	1.40
Variety	8	0.00171	9.64**
Error	16	0.00018	

** = Highly significant (P<0.01)

Table-22a A Comparison of Means for the Data Regarding Leaf Thickness (mm) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	0.627±0.007 BC
US-133	0.617±0.012 CD
US-312	0.617±0.012 CD
SPF-234	0.597±0.009 DE
US-1491	0.637±0.003 ABC
US-824	0.647±0.009 AB
CPF-246	0.660±0.006 A
US-718	0.613±0.003 CD
CPF-237	0.583±0.003 E

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

Table 23 Analysis of Variance Table for Plant girth (cm)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.0489	1.76
Variety	8	0.5332	19.20**
Error	16	0.0278	

** = Highly significant (P<0.01)

Table-23a A Comparison of Means for the Data Regarding Plant Girth (cm²) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	5.13±0.035 B
US-133	4.73±0.052 CD
US-312	5.23±0.052 AB
SPF-234	4.56±0.205 CDE
US-1491	5.43±0.145 AB
US-824	5.47±0.085 A
CPF-246	4.37±0.059 E
US-718	4.78±0.074 C
CPF-237	4.44±0.067 DE

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

4.7.6 Chemical plant Factors

4.7.6.1 Total Minerals (%):

Significance difference was recorded among the varieties data regarding total minerals percentage. The maximum percentage was found in varieties CPF-246 and CPF-237 which was similar in both varieties 7.29 %. The minimum percentage was recorded in variety US-312 (7.19%) which was not significantly different from SPF-234 and US-824 with 7.20%. The varieties US-133, US-1491 and US-718 with 7.25% and US-676 with 7.24% showed non significance difference from one another significance different from other varieties.

4.7.6.2 Nitrogen (%):

The data regarding nitrogen percentage in different sugarcane varieties was significant. The analysis of variance and mean comparison were compared by Tukey HSD test (0.05). The variety US-312 showed minimum percentage of nitrogen 1.03% which significantly different from CPF-246 and US-718 with similar nitrogen percentage 1.06%.

The variety US-133 showed maximum percentage of nitrogen 1.14% followed by US-1491 with 1.13%. The varieties US-676, SPF-234 and CPF-237 showed 1.07% of nitrogen while US-824 showed 1.08% which significantly different from other varieties.

4.7.6.3 Phosphorous (%):

The analysis of variance data regarding phosphorous percentage in various sugarcane varieties were highly significant. The maximum phosphorus percentage was recorded in 0.24% in variety CPF-246 after US-676 with 0.23% which were significantly different from other varieties. The variety US-1491 showed minimum percentage of phosphorus with 0.19% which similar in varieties SPF-234 and US-718. The variety US-824 possessed 0.23% N and was at par with those of recorded in CPF-237, US-312 and US-133.

4.7.6.4 Potassium (%):

The data regarding potassium percentage in selected varieties of sugarcane revealed that maximum percentage of P was recorded in SPF-234 with 0.24% followed by 0.22% in varieties US-1491 and US718 while 0.21 percent in varieties US-312 and US-824 which significantly difference from all other varieties. The minimum percentage of P was recorded in variety US-676 which significantly highly different from other varieties. The varieties US-

133 and CPF-234 showed P percentage 0.19% while variety CPF-237 showed 0.18% which significantly different from other.

4.7.6.5 Calcium (%):

It is evident from the results that difference was significant among the varieties. The means were compared by Tukey HSD test (P=0.05). The minimum calcium percentage was recorded in variety US-824 with 0.18% similar in SPF-234 after US-718 with 0.19% respectively. The maximum percentage of calcium was found in US-1491 and US-676 with similar 0.24% which significantly different from other. The US-133 and CPF-246 showed 0.23% calcium which did not significantly different from US-312 and CPF-237 with 0.22%.

Table-24 Analysis of Variance Table for Total Minerals (%)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.00025	0.52
Variety	8	0.00405	8.41**
Error	16	0.00048	

** = Highly significant (P<0.01)

Table-24a A Comparison of Means for the Data Regarding Total Minerals (%) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	7.24±0.012 C
US-133	7.25±0.024 BC
US-312	7.19±0.007 D
SPF-234	7.20±0.012 D
US-1491	7.25±0.009 BC
US-824	7.20±0.012 D
CPF-246	7.29±0.013 A
US-718	7.25±0.007 BC
CPF-237	7.29±0.007 AB

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05

Table-25 Analysis of Variance Table for Nitrogen (%)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.00051	1.24
Variety	8	0.00379	9.14**
Error	16	0.00041	

** = Highly significant (P<0.01)

Table-25a A Comparison of Means for the Data Regarding Nitrogen (%) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	1.075±0.035 B
US-133	1.147±0.002 A
US-312	1.034±0.001 C
SPF-234	1.073±0.002 B
US-1491	1.135±0.002 A
US-824	1.089±0.002 B
CPF-246	1.068±0.002 BC
US-718	1.064±0.001 BC
CPF-237	1.073±0.002 B

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

Table-26 Analysis of Variance Table for Phosphorous (%)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.0000124	0.58
Variety	8	0.0011533	54.20**
Error	16	0.0000213	

** = Highly significant (P<0.01)

Table-26a A Comparison of Means for the Data Regarding Phosphorous (%) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	0.237±0.003 AB
US-133	0.213±0.004 D
US-312	0.224±0.002 C
SPF-234	0.198±0.003 E
US-1491	0.191±0.002 E
US-824	0.237±0.002 AB
CPF-246	0.244±0.001 A
US-718	0.199±0.002 E
CPF-237	0.230±0.002 BC

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

Table-27 Analysis of Variance Table for Potassium (%)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.000011	1.73
Variety	8	0.003432	527.19**
Error	16	0.000007	

** = Highly significant (P<0.01)

Table-27a A Comparison of Means for the Data Regarding Potassium (%) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	0.125±0.001 F
US-133	0.190±0.001 E
US-312	0.217±0.001 C
SPF-234	0.243±0.002 A
US-1491	0.222±0.001 B
US-824	0.210±0.001 D
CPF-246	0.192±0.001 E
US-718	0.222±0.002 B
CPF-237	0.188±0.002 E

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

Table-28 Analysis of Variance Table for Calcium (%)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.000004	0.33
Variety	8	0.001926	154.22
Error	16	0.000013	

** = Highly significant (P<0.01)

Table-28a A Comparison of Means for the Data Regarding Calcium (%) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	0.240±0.001 B
US-133	0.230±0.001 C
US-312	0.220±0.002 D
SPF-234	0.181±0.002 F
US-1491	0.249±0.002 A
US-824	0.181±0.002 F
CPF-246	0.232±0.002 C
US-718	0.196±0.001 E
CPF-237	0.229±0.002 C

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

4.7.6.6 Magnesium (%):

Significant differences were found among the selected varieties of sugarcane against the sugarcane stem borer. The maximum Mg percentage was recorded in SPF-234 with 0.24% followed by US-676, US-1491 and CPF-237 with similar percentage of Mg 0.23 % which significantly different from other. The minimum Mg percentage was recorded in US-824 with 0.19% which was significantly different from other varieties. The variety CPF-246 showed 0.22% Mg which did not significantly different with US-718 with 0.21% and US-312 with 0.20%.

4.7.6.7 Copper (ppm):

Differences were found highly significant among the selected varieties of sugarcane regarding to the concentration of Copper. The means were compared by Tukey HSD test (0.05). The minimum concentration was recorded in SPF-234 with 3.58ppm which significantly different from US-718 and CPF-246 with 3.73 and 3.65ppm. The maximum concentration was found CPF-237 with 4.25ppm followed by US-676, US-133 and US-312 with 4.18, 3.97 and 3.84ppm which significantly different from other. The varieties US-1491, US-824 and US-718 showed the intermediate concentration with 3.78ppm, 3.74ppm and 3.73ppm which did not significant from one another while significant from other varieties.

4.7.6.8 Ferrous (ppm):

The analysis of variance data regarding ferrous percentage in various sugarcane varieties were highly significant. The maximum concentration of ferrous was recorded in US-312 with 31.70ppm did not significant from CPF-237 with 31.63ppm. The minimum was recorded in US-824 with 28.49ppm. The US-133 with 29.74ppm showed significant with US-1491 and CPF-246 with 29.66 and 29.81ppm. The US-676 with 30.40 did not showed significant with US-718 with 30.59ppm while significant from US-824 with 28.49ppm.

4.7.6.9 Manganese (ppm):

It is evident from the result that differences were significant among the varieties regarding to manganese contents. The maximum contents was recorded in SPF-237 with 37.34ppm followed by US-1491, CPF-237 and US-133 with manganese contents 36.48, 36.45 and 35.60ppm which significantly different from other. The minimum contents were revealed in US-312 with 30.73ppm.The US-824, US-718, US-676 and CPF-246 showed

manganese contents with 34.56, 34.29, 32.57 and 32.53ppm respectively which significantly different from other.

4.7.6.10 Zinc (ppm):

Differences were found highly significant among the selected varieties against the sugarcane stem borer. The means were compared by Tukey HSD test (P=0.05). The minimum contents were recorded in 18.50ppm in US-718. The maximum contents were recorded in SPF-234 (22.60ppm) which did not significant from US-1491 and CPF-237 with zinc contents 22.51 and 21.65ppm respectively. The US-824 (20.67ppm) did not significant from US-133 with 20.51ppm but significantly different from the US-676, CPF-246 and US-312 with zinc contents 19.71, 19.65 and 19.59 respectively

Table-29 Analysis of Variance Table for Magnesium (%)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.000025	1.45
Variety	8	0.000732	41.59**
Error	16	0.000018	

** = Highly significant (P<0.01)

Table-29a A Comparison of Means for the Data Regarding Magnesium (%) in various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	0.232±0.001 B
US-133	0.216±0.002 C
US-312	0.207±0.002 D
SPF-234	0.240±0.001 A
US-1491	0.234±0.002 AB
US-824	0.190±0.003 E
CPF-246	0.220±0.002 C
US-718	0.214±0.003 CD
CPF-237	0.230±0.003 B

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

Table-30 Analysis of Variance Table for Copper (ppm)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.00030	0.48
Variety	8	0.15952	255.67**
Error	16	0.00062	

** = Highly significant (P<0.01)

Table-30a A Comparison of Means for the Data Regarding Copper (ppm) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	4.18±0.025 B
US-133	3.97±0.012 C
US-312	3.84±0.011 D
SPF-234	3.58±0.011 H
US-1491	3.78±0.009 E
US-824	3.74±0.010 EF
CPF-246	3.65±0.006 G
US-718	3.73±0.021 F
CPF-237	4.25±0.010 A

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

Table-31 Analysis of Variance Table for Ferrous (ppm)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.0045	0.14
Variety	8	3.0234	91.43**
Error	16	0.0331	

** = Highly significant (P<0.01)

Table-31a A Comparison of Means for the Data Regarding Ferrous (ppm) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	30.40±0.07 B
US-133	29.74±0.04 C
US-312	31.70±0.08 A
SPF-234	30.55±0.10 B
US-1491	29.66±0.07 C
US-824	28.49±0.12 D
CPF-246	29.81±0.08 C
US-718	30.59±0.11 B
CPF-237	31.61±0.17 A

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

Tabl-32 Analysis of Variance Table for Manganese (ppm)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.0430	0.66
Variety	8	14.5720	220.86**
Error	16	0.0660	

** = Highly significant (P<0.01)

Table-32a A Comparison of Means for the Data Regarding Manganese (ppm) in Various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	32.57±0.19 E
US-133	35.60±0.11 C
US-312	30.73±0.15 F
SPF-234	37.34±0.07 A
US-1491	36.48±0.20 B
US-824	34.56±0.07 D
CPF-246	32.53±0.16 E
US-718	34.29±0.20 D
CPF-237	36.45±0.04 B

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

Table-33 Analysis of Variance Table for Zinc (ppm)

Source of variation	Degrees of freedom	Mean squares	F-value
Replication	2	0.0273	0.44
Variety	8	5.9677	97.07**
Error	16	0.0615	

** = Highly significant (P<0.01)

Table-33a A Comparison of Means for the Data Regarding for Zinc (ppm) in various Chosen Varieties of Sugarcane

Varieties	Mean (%)
US-676	19.71±0.07 D
US-133	20.51±0.10 C
US-312	19.59±0.13 D
SPF-234	22.60±0.12 A
US-1491	22.51±0.14 A
US-824	20.67±0.11 C
CPF-246	19.65±0.25 D
US-718	18.50±0.13 E
CPF-237	21.65±0.13 B

Means sharing similar letters are statistically non-significant by Tukey HSD test at (P>0.05)

Table-34 Correlation Between Infestation and Various Sugar Characters

Factors	Correlation (r)
X1 - Fiber	-0.291
X2 - Brix	-0.650
X3 - POL	-0.683*
X4 - CCS	-0.643

Table-35 Regression analysis for sugar factors

Regression Equation	R^2
$Y = 18.9 - 0.275\ X_1$	0.085
$Y = 22.1 - 0.147\ X_1 - 0.223\ X_2$	0.446
$Y = 13.4 - 0.073\ X_1 + 1.33\ X_2 - 1.38\ X_3$	0.585
$Y = 11.6 + 0.056\ X_1 + 1.52\ X_2 - 1.91\ X_3 + 0.434\ X_4$	0.614

Y = Infestation (%)

4.8 Chemical Control:

Four insecticides were tested against the sugarcane stem borer (*Chilo infuscatellus*). The results are given in Fig-4 that showed a significant difference among the treatments. The means were compared by Tukey HSD test which revealed that the minimum increase in infestation 10.22% after the treatments with Furadan followed by Thimet, Padan and Monomehypo which showed 11.35, 12.45 and 13.84% increased infestation respectively. Maximum infestation (26.13%) was observed in control treatment

4.9 Biological Control:

This experiment was carried out to test different treatments of egg-releases of *Trichogramma chilonis*, for the management of sugarcane stem borer (*Chilo infuscatellus*). The treatments applied when the population of the pest was at the peak point. The results regarding this study are given in Fig-5 which showed that there was a significant difference among the treatments. The means compared by Tukey HSD (P=0.05) given in Fig-5 which revealed a minimum infestation 9.31% in treatment T_1 followed by T_2, T_3 and T_4 with infestation percentage 13.60, 17.07 and 19.44%. The maximum infestation was recorded in control treatment with 25.95%. The Minimum infestation (16.57%) was observed after 10 days intervals followed by 15 and 20 days interval with 17.14 and 17.52%.

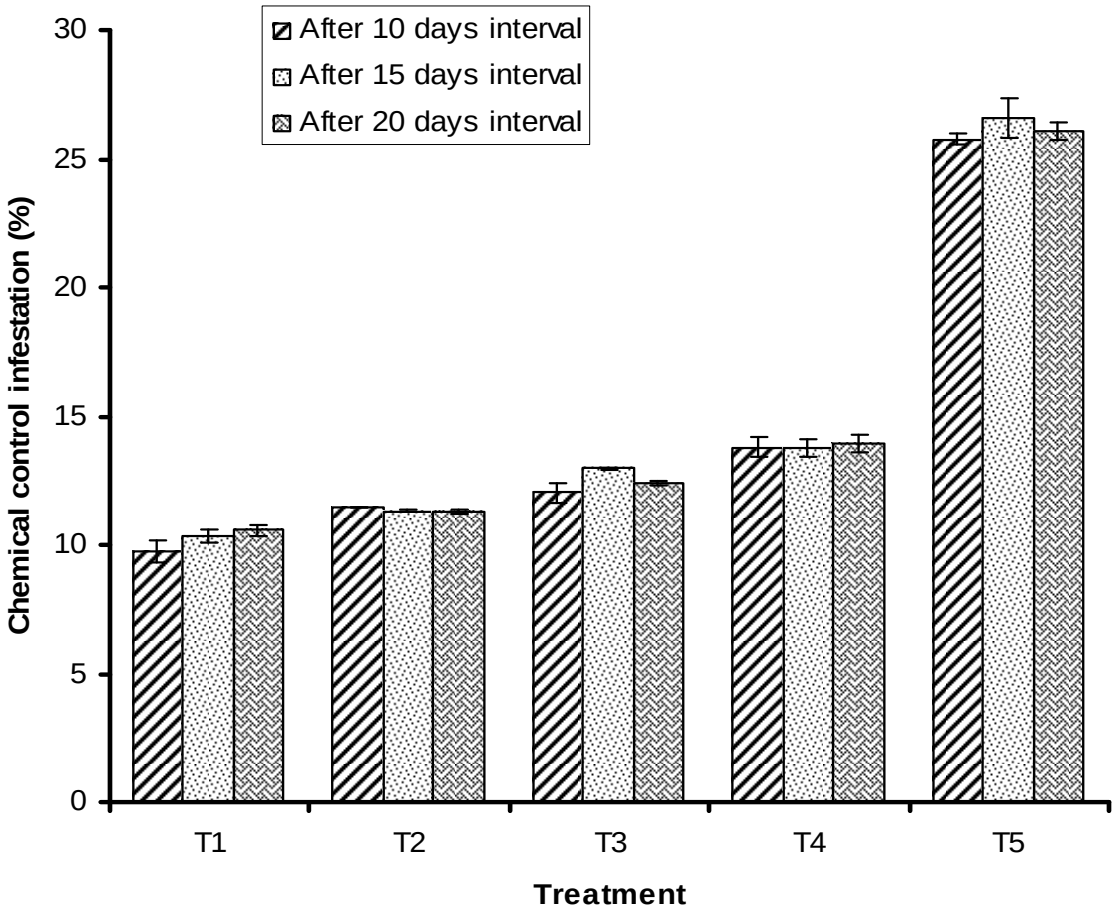
4.10 Cultural and Mechanical Control:

The main objective was to find out the various cultural and mechanical controls to evaluate against the sugarcane stem borer. The results of these studies, given in Fig-6 show a significant difference among the treatments. The means compared by Tukey HSD test (P=0.05). The minimum infestation (12.91%) in treatment T_1 which significant different from other treatment. The maximum infestation (25.71%) was recorded in control T6. The treatment T_2 showed 14.09% infestation followed by T_3, T_4 and T_5 with 15.69, 16.00 and 16.84% respectively. The infestation was maximum (17.08%) after 20 days intervals while it was minimum (16.84%) after 10 days intervals.

4.11 Integration of Various Controls:

This experiment was conducted to evaluate different controls against the sugarcane stem borer. The means were compared by Tukey HSD test (P=0.05). The minimum infestation (8.71%) was revealed in T_7 followed by 8.92, 9.34 and 9.74% T_3, T_1 and in T_4.

The treatment T_8 showed 10.46% infestation was significant different from $_{T6}$, T_9 with infestation 11.66 and 11.86%. The treatment T_2 with infestation 12.39% did not showed significant difference from T_5 with 12.82. The maximum infestation was observed in control treatment with 25.45%. The minimum infestation 11.66% was recorded after 10 days interval followed by 15 days interval 12.21% while maximum infestation 12.53% was observed after 20 days interval.



T_1 = Furadan 3G carbofuran @ 12 kg/acre

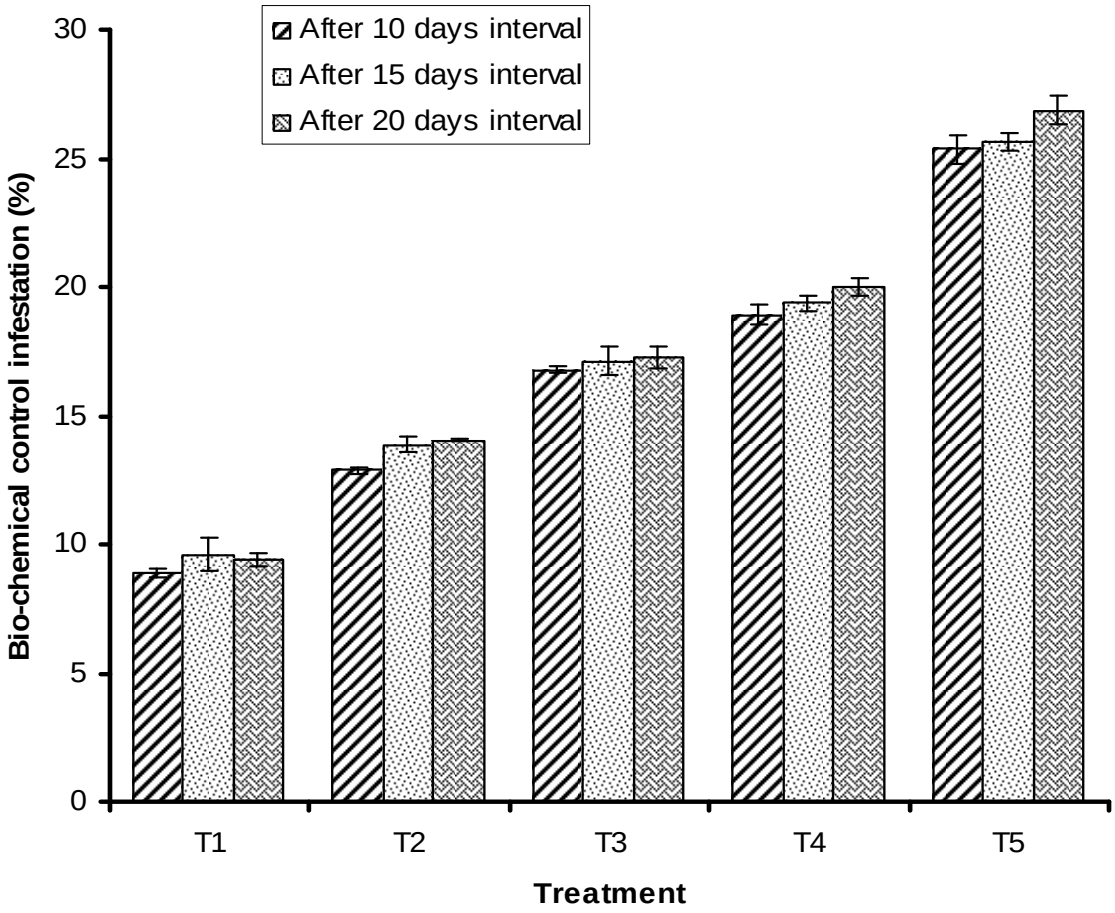
T_2 = Thimet 5G Phorate @ 10 kg /acre

T_3 = Padan 4G Cartap @ 10 kg/acre

T_4 = Monomehypo @ 8kg/acre

T_5 = Control

Fig-4 Graph between Chemical Control and Infestation (%)



T_1 = 72000

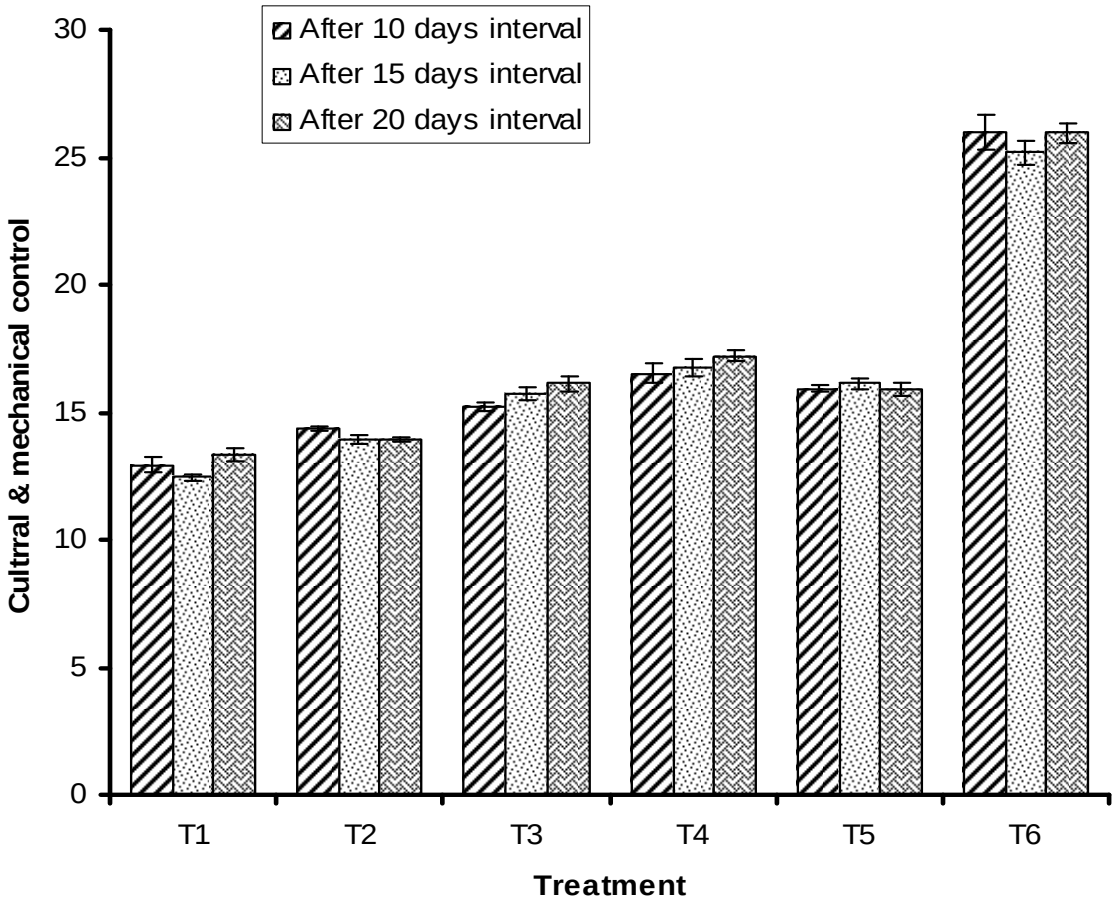
T_2 = 60000

T_3 = 48000

T_4 = 40000

T_5 = Control

Fig-5 Graph between Biological Control and Infestation



T_1 = Trash mulching

T_2 = Light traps

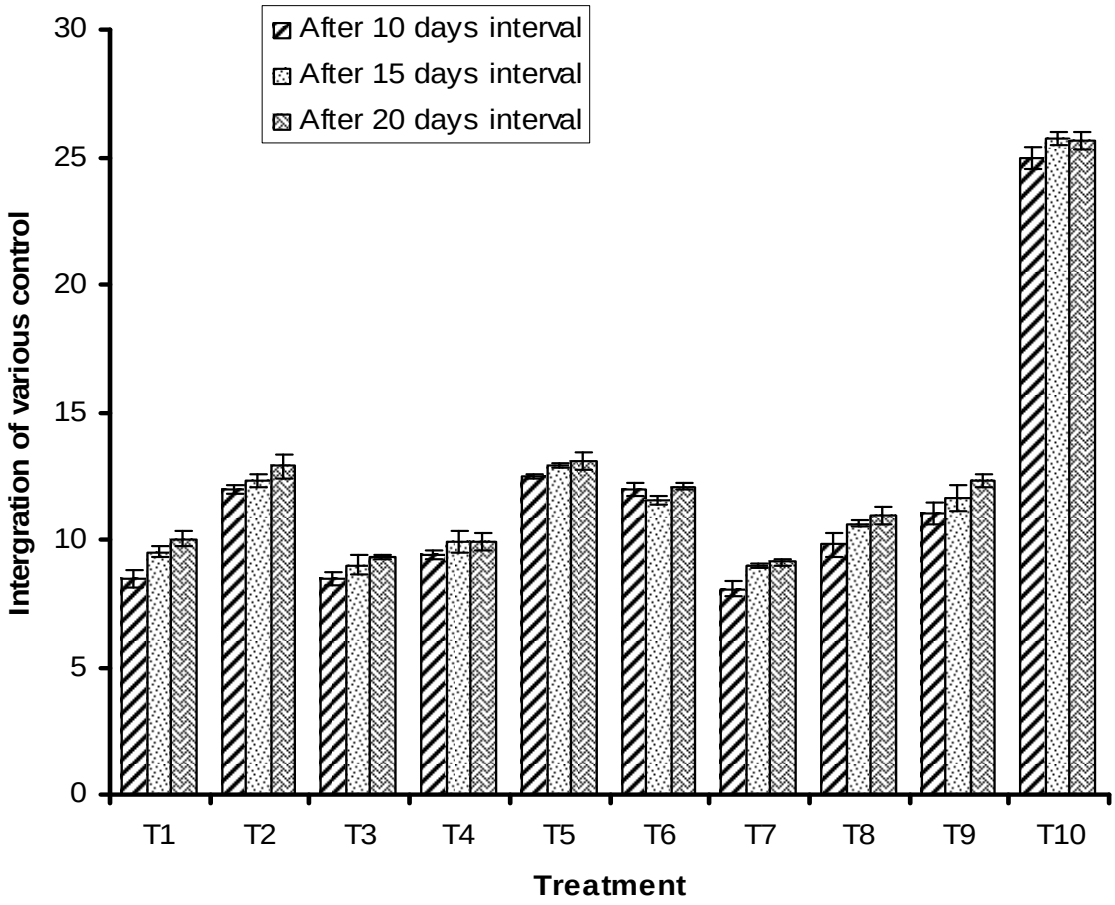
T_3 = Propping

T_4 = Hand collection of egg masses

T_5 = Detrashing

T_6 = Control

Fig-6 Graph between Cultural & Mechanical Control and Infestation



T_1 = Trichogramma cards + Detrashing

T_2 = Trichogramma cards + Chemical control

T_3 = Trichogramma cards + Light Traps

T_4 = Detrashing + Chemical control

T_5 = Detrashing + light traps

T_6 = Trichogramma cards + Detrashing + Chemical control

T_7 = Trichogramma cards + Detrashing + Light traps

T_8 = Trichogramma cards + Chemical control + Light traps

T_9 = Chemical control + Light trap + Detrashing

T_{10} = Control

Fig-7 Graph between Integration of Various Controls and Infestation

Chapter-5

DISCUSSION

The experiment was carried out to work on integrated pest management of sugarcane stem borer (*Chilo infuscatellus*) in Punjab, Pakistan during 2008-09. The basic aim of the studies were find out the comparatively resistance/susceptible varieties of sugarcane against the sugarcane stem borer (*Chilo infuscatellus*) and to check the affect of abiotic (Temperature, relative humidity and rainfall), Physcio-Morphic, Chemical, and Qualitative factors. The studies were also done on the biological, mechanical, cultural, chemical control and integration of all these control against the sugarcane stem borer. The results are discussed under;

5.1 Varietal Resistance:

The results revealed that there were significant variations among the varieties. US-718 showed comparatively resistant with minimum infestation (15.49%) and US-394 found susceptible and showing maximum infestation (21.90%). The infestation of other varieties was given under descending order towards the susceptibility during 2008 are as, NSG-555 > BL-4 > US-162 > L-116 > CP-77-400 > CPF-237 > US-312 > US-1491 > US-824 > CPF-246 > SPF-234 > US-676 > US-133. In present study NSG-555 showed susceptible against sugarcane stem borer. The present results can not compare with those of Baloach *et al*. (2005) and Rafiq *et al.* (2007) who found that NSG-555 showed least resistance against the stem borer. It is also concluded that BL-4 showed moderately resistant against stem borer, these findings are partially compared with those of Memon *et al*. (2003), Keerio *et al*. (2003) who reported that the Bl-4 showed minimum infestation. It is also conformity by Mushtaq *et al.* (1989) who found that BL-4 showed least infestation against the stem borer. Our findings are contradict with Sohu *et al*. (2008) who recorded that L-116 showed very good results against sugarcane borer. The present findings showed that results contradict with those of Zafar *et al.* (2005) who's reported that CP-77-400 showed poor growth against the stem borer.

In the present experiment nine varieties were selected from fifteen varieties as mention which showed resistant, susceptible and intermediate responses. The level of infestation was low during 2009 as compared to the 2008. US-718 showed infestation

14.44% and CPF-237 showed 15.95% while it was 17.81% during 2008. The descending order of the varieties towards the susceptibility, CPF > 237 > SPF-234 > US-824 > US-133 > US-676 > US-1491 >CPF-246 > US-312 > US-718. The present finding cannot compared with those of Bahadar *et al.* (2007); Sarwar *et al.* (2002); Ali *et al.* (2002) and Shah *et al.* (2005) who found that CPF-237 showed least resistance against borer.

The results showed that the period of infestation was variable during both the years. There was maximum infestation 30.25% during 4th week of the August. This was the most favorable period for the pest fluctuation during 2008. The trend was quite different during 2009. The 4th week of May was most favorable and increased the pest infestation 22.65% followed by the infestation 21.16% during the second week of the July. The infestation decreased suddenly during both of the years. From the result it was concluded that borer population was high during 2008 as compared to 2009. The present findings are confirmatory with Aheer *et al.* (1994) who reported that borer population was maximum during the month of July and August. The present findings are not comparable with those of Rana *et al.* (1992) who reported that highest population of stem borer was recorded during 4th week of May, 4th week of August and 2nd week of September. These findings can partially comparable with those of Bhati *et al.* (2008) whose reported that maximum damage done by the stem borer during the month from April to July.

5.2 Role of Abiotic Factors on Sugarcane Stem Borer:

The impact of weather factors like Relative humidity, Temperature and Rainfall on the infestation and population was tested during 2008-09. Simple correlation and multiple regression models was worked out for determination the effect of weather factors on the population fluctuation of both of the years separately as well as collectively. The results revealed that rainfall showed positive and highly significant correlation with infestation during both years 2008-09, as well as on cumulative basis. Similarly relative humidity showed positive and significant correlation with infestation during both years 2008-09, as well as on cumulative basis. There was positive and non-significant correlation between maximum and minimum temperature during both years 2008-09 but negative and non-significant on cumulative basis. The present findings are conformity those of Rustamani *et al.* (1997) who reported non-significant and positive effect of temperature on stem borer population. In multiple regression analysis temperature and relative humidity showed

positive and non-significant impact on the stem borer population. These findings are conformity with those of Mahmood (1989). The present findings are contradicted with those of Anonymous (1995-96) which showed non-significant and negative impact of relative humidity and rainfall with borer infestation. The present findings are also comparable with those of Shah *et al.* (1981) who reported that rainfall and relative humidity showed positive and temperature showed negative impact on the borer infestation. The present findings are non comparable with those of Nagaraja and Chanty (1957) who reported positive impact of the temperature with borer infestation.

5.3 Physico–Morphogical and Qualitative Plant Factors:

The effect of physico-morphological and qualitative plant factors on the population of sugarcane stem borer were calculated by processing the data into simple correlation and multiple linear regression of variance. It is evident from the results that all the physico–morphological plant factors like plant girth, leaf area, leaf sheath hairiness and leaf thickness showed significantly different variations towards the borer infestation. The plant girth, leaf area, leaf sheath hairiness and leaf thickness showed negative and non significant correlation with pest infestation. The present findings are contradict with those Khaliq *et al.* (2005) whose reported that leaf thickness, cane girth and leaf area showed positive and significant correlation with borer infestation. The present findings are not comparable with those of Khan *et al.* (2006) who reported that there was no relation between plant girth and stem borer infestation

All the qualitative plant factors like Fiber, Brix, POL and CCS showed significant variations. Brix and POL percentage showed negative and significant correlation with pest infestation, while fiber contents and CCS showed negative and non-significant correlation with infestation. The present findings are contradict with those of Khan *et al*. (2006) who showed that there is no relation between Brix and stem borer infestation. The present findings are partially comparable with those of Gupta and Sing (1997) who reported that Brix, POL, Fiber contents and CCS are affected by the borer infestation. Similarly the present findings are partially comparable with those of Chang and Wang (1995) reported that Sugar contents, Brix and sugar purity are heavily affected by sugarcane borer. The present findings can be comparable with those of Khaliq *et al.* (2005) who's reported that CCs, POL% and Brix contents showed significantly and negative effect on the borer infestation.

The coefficient of determination value 0.821 was obtained by computing Brix, Fiber content, POL, and CCS factors mutually for multivariate regression models.

5.4 Chemical Plant Factors:

The macro and micro nutrients deficiency slow down the plant growth and development (Fragoyiannis *et al*., 2001; Jansson and Ekbom, 2002). The reduction of proportion nitrogen in plant retarded the growth of herbivorous insects (Scriber and Slansky, 1981). The Cornelissen and Fernandes (2001) reported that the absorption of sugars in leaves affects the area of leaf damaged by herbivores in Bauhinia brevipes. Comes (1916) reported that the accessibility of plants increases with the quantity of reducing sugars, and resistance increases with organic acids. The quantity of reducing sugars, affected by insects which increase the vegetable tissues, as result reduction in the organic acids.

The effect of chemical plant factors on the population of sugarcane stem borer were calculated by processing the data into simple correlation and multiple linear regression of variance. It is evident from the results that impact of moisture, Total Minerals, Potassium, Calcium, Ferrous and Fat was negative and non significant while other factors Carbohydrate, Nitrogen, Phosphorous, Magnesium, Copper, Manganese and Zinc showed positive and non significant impact on pest infestation. The present findings are partially comparable with those of Khaliq *et al.* (2005) who reported that there are total minerals, copper and manganese showed non significant correlation with borer infestation. The present findings are also comparable with same scientist who reported that positive relationship with Nitrogen and Magnesium but contradict with carbohydrates, fats, moisture Phosphorous, Zinc Potassium, Calcium and Ferrous showing non significant correlation with borer infestation. The present findings are comparable with those of Saikia *et al.* (1998) who reported that Total minerals, copper and Manganese showed non significant correlation with infestation and also the level of Nitrogen increase with increase of infestation.

5.5 Chemical Control

Four insecticides were evaluated against the sugarcane stem borer after 10, 15 and 20 days interval. The results showed significant difference among the treatments. The minimum infestation was recorded 10.22% by using Furadan. The Thimet, Padan and Monomehypo showed 11.35%, 12.45% and 13.84% increased infestation. The

infestation was almost same with three intervals respectively. Maximum infestation (26.13%) was observed in control treatment.

The present findings are comparable with those of Halimie *et al*. (1994), Marwat and Khalid (1985), Rana *et al.* (1992) and Mishra *et al.* (1998) who reported that Furadan is very effective against the sugarcane stem borer. The present findings are comparable with those of Talpur and Qureshi (2002) who suggested that Furadan 3G, Padan 4G and Thimet 5G before and after 10, 15 and 30 days was very effective against the sugarcane borer. The Furadan showed very effective results to control the stem borer as compared to the other insecticides. The present findings are comparable with those of Madan *et al*. (1998), Halimie *et al.* (1989) who reported that the use of insecticides at initial stages gave best results and reduced the infestation from 4.48% to 3.63%. These findings are contradict with those of Bessin *et al.* (1990) who reported that insecticides effect the predominantly on the plant injury. These findings are not comparable with those of Yunus and Hussain (1973) who tested seven insecticides including Furadan and Thiodan and diazinim etc, against the sugarcane stem borer and find that it was not good result on larvae when applied three times at the 25 days interval.

5.6 Biological Control:

It is evident from the results that there was a significant difference among the treatments. The results showed that minimum infestation 9.31% calculated by installing 40,000 *Trichogramma* cards followed by 48000, 60000 and 72000 cards with infestation percentage 13.60%, 17.07% and 19.44%. The maximum infestation was recorded in control treatment with 25.95%. The Minimum infestation (16.57%) was observed after 10 days intervals followed by 15 and 20 days interval with 17.14% and 17.52%.

The present findings are partially compared with those of Rafique *et al.* (2007), Zia *et al.* (2007) who reported that when 60000 eggs of *Trichogramma* per acre were released causing 83% reduction of *Chilo infuscatellus* and showed significant result and also reported that population of *Chilo infuscatellus* showed a negative correlation with an increase in number of eggs which indicated that it can successfully used to control stem borer. The present findings are comparable with those of Muhammad and Muhyuddin (1987) who reported that use of *Trichogramma,* adversely affect natural enemies of sugarcane stem borer *Chilo infuscatellus.* Similarly, Mustafa *et al.* (2006), Ashraf *et al.* (I993) reported

that by using *Trichogramma,* infestation was reduced 52.04% to 60.03% during 2000-01 and damage ranged from 3.9% to 10.5% in treated area and 9.6% to 18.6% in untreated plots. The internodes damaged reduce due to *Trichogramma* treated ranged from 28.6% to 59.7%. The present findings are also comparable with those of Shenhmar *et al*. (2003), Rajendran and Hanifa (1996) who reported that *Trichgramma* is very effective against the sugarcane borers. The present findings are comparable with those of Nadeem *et al*. (2009) and Sajad *et al.* (2009) who reported that the temperature for *Trichogramma chilonis* at 20, 25, 28, 31, 35 and 40^{o}C in the incubators. The biological parameters such as parasitism 95.6%, emergence 98.0%, developmental period 7.3 days and adult longevity 9 days were very favorable at 28^{o}C. It was also reported that 40^{o}C and low 20^{o}C temperature did not support the development period while temperature at 28^{o}C was most favorable for the rearing of *Trichgramma chilonis.*

5.7 Cultural and Mechanical Control:

It is evident from the results the minimum infestation 12.91% was recorded by using Trash mulching while the maximum infestation 25.71% was recorded in control treatment. The results showed that by using detrashing showed 14.09% infestation followed by using Propping, Egg collecting and light traps with 15.69%, 16% and 16.84% respectively. The infestation was maximum (17.08%) after 20 days intervals while it was minimum (16.84%) after 10 days intervals.

The present findings are comparable with those of Jalali *et al,* (2000), Makhdom *et al.* (2001) who reported that effect of trash mulching on sugarcane crop against the stem borer (*Chilo infuscatellus*) was very effective. The borer population was significantly suppressed in plots treated as trash mulching compared with trash burnt plots. This was because of the parasitoid activities in trash mulching plots. They reported that sugarcane yield was significantly increased in trash mulching plots. These present findings are also comparable with those Subramanian and Lyer (1921), Flecher (1990), Gupta and Avasthy (1954), and Athwale (1953) who reported that hand collection of egg masses and their destruction before the formation of node reduce the pest population. The present findings are comparable with those of Jena *et al.* (1997) who reported that cultural control practices i.e. burning of trash, removing plants residue and removing water shoots reduce the pest population 8.23%. The present findings are comparable with those of Hashmi (1994) who

reported that sugarcane infested parts should be cut and fed to cattle and strong earthing-up is very effective against the borer control in sugarcane.

5.8 Integration of Various Controls:

From the results it was concluded that the minimum infestation 8.71% was recorded by using the integration of *Trichogramma* cards + detrashing + light traps followed by integration of *Trichogramma* cards + light traps, *Trichogramma* cards + detrashing and detrashing + chemical control with infestation 8.92%, 9.34% and 9.74% respectively. The integration of *Trichogramma* cards + chemical control + light traps showed 10.46% infestation which was significant different from the integration of *Trichogramma* cards + detrashing + chemical control and chemical control + light trap + detrashing integration with infestation 11.66% and 11.86%. The integration of *Trichogramma* cards + chemical control with infestation 12.39% did not showed significant difference from the integration of detrashing + light traps with 12.82% infestation. The maximum infestation was observed in control treatment with 25.45%. The minimum infestation 11.66% was recorded after 10 days interval followed by 15 days interval 12.21 % while maximum infestation 12.53% was observed after 20 days interval.

The present findings are comparable with those of Gul *et al.* (2008) who reported that the combinations of all control reduced the borer infestation and increased the sugarcane yield as result low the infestation and high the sugarcane yield when all control methods applied in combination. The present findings are comparable with those of Jena *et al.* (1999) who reported that collectively showed that plots treated with cultural, mechanical and chemical control showed minimum infestation against stem borer 0.27%. The present findings are comparable with those of Subramanian *et al.* (1997) who reported that the trash mulching and chemical method were compared for the control of sugarcane stem borer. They compared different insecticides with the ash mulching, whereas granular formulations of trichlorphos, disulfaton, fensulfithion, phorate, Carbyral + Lindane and aldicarb were tested along with Endrin and trash mulching. The results showed that trash mulching is effective as the other two applications of the best insecticides namely Endrin 20% or Carbyral + Lindane 4% for the control of pest. The present findings are also comparable with those of Sharma *et al.* (1997) and Jena *et al.* (1997) who reported that

combination of different control like cultural control methods, frequent irrigation, trash mulching, earthing up and application of monocrotophos showed 2.7 to 2.8% against *Chilo infuscatellus* and maximum sugarcane yield 15.04 to 16.05 tons/ha. The installation of *Trichogramma chilonis* cards and cultural control were equally successful to reduce the pest population. The earthing-up in May and June, detrashing cane and removing of shoots, applying fertilizers were effective for the control of sugarcane stalk borer.

The present findings are also comparable with those of Saroj and Jaipal (2000) who reported that integration of these tactics reduced insect pests damage, cost of control and yield of sugarcane was significantly increased up to 22-36%. The results are also conformity with those of Jalali *et al.* (2000) who reported that the combination of different controls like, cutting of attacked shoots, removal of dead hearts and spike thrust, application of trash mulch and application of Furadan 3G @ against sugarcane borer showed very good results. It was also noted the trash mulching reduced the infestation 9.61% to 13.85% increased the sugarcane yield 109.50 to 110.13 ton/hac. The present findings are conformity with those of Jan *et al.* (1993, 1995) who reported that the integration of different controls, balanced fertilization, strong earthing-up, early harvesting, rouging of dry shoots, tops, application of Furadan showed very effective controlled against the sugarcane borers. The present findings are comparable with those of Sharma *et al.* (1997), Gul and Saeed (2007) who reported that the integration of different controls like trash mulching, frequent irrigation, earthing up and application of monocrotophos showed very low infestation from 2.7 to 3.8% against *Chilo infuscatellus* and high yield 15.4-16.5 tons/ha. Similarly by using the *Trichogramma chilonis* and cultural control reduce the pest population and increasing sugarcane yield. The Integrated control methods including mechanical, destruction of borer egg masses and infested plants and shaving of stubbles, releasing of egg parasitoid *Trichogramma* eggs after 15 days interval and chemical application of Furadan granules reduce the borer infestation. The present findings are also comparable with those of Zubir *et al.* (2007), Jena *et al.* (1997), Hashmi and Rehman, (1985) who reported that the integration of various contols *Trichogramma chilonis*, trash mulching, earthing-up, detrashing, removing shoots and applications of fertilizers against the sugarcane stem borer *Chilo infuscatrllus* showed very effective results.

Chapter-6

SUMMARY

Comprehensive Studies were conducted on the integrated pest management of sugarcane stem (*Chilo infuscatellus)* during 2008-09. Preliminary screening was done during 2008; Fifteen sugarcane varieties viz., US-676, US-133, US-312, SPF-234, US-1491, US-824, CPF-246, US-718, CPF-237, CP-77-400, US-162, NSG-555, BL-4, L-116 and US-394 were tested base on the percentage infestation caused by sugarcane stem borer during 2008. The variety US-394 showed maximum infestation 21.90% and at par with NSG-555 (21.60%) which significantly different from other varieties BL-4, US-162, US-394, L-116 and CP-77-400 with infestation 20.73%, 20.38%, 19.64% and 19.51% respectively. The variety US-718 showed minimum infestation 15.49% after US-133 and US-676 with 15.59% and 16.46%. The variety CPF-237 showed 17.81% which significantly different from US-312, US-1491, US-824 and CPF-246 with 17.15%, 17.12%, 17.08% and 16.95% respectively. The maximum infestation was recorded during 4th August and minimum was recorded during 2nd week of the April, 2008.

From the preliminary screening, nine varieties were screened out. The minimum infestation was observed on US-718 (14.45%), which statistically at par with that of US-312 (14.80%), CPF-246 (14.90%) and significantly different from varieties US-4191, US-678, US-133, US-824, CPF-234 and CPF-237 with infestation percentage 15.02%, 15.28%, 15.72%, 15.83%, 15.90% and 15.95% respectively against the *Chilo infuscatellus* during 2009. The maximum infestation 22.65% was observed during 4th week of May and minimum observed during 4th week of the August, 2009.

The impact of abiotic factors was also studied on the varieties selected from preliminary screening. The relative humidity and rainfall showed positive and highly significant correlation with infestation with r value 0.529% and 0.765%, while maximum temperature showed negative and non significant correlation with infestation 0.064% while minimum temperature showed positive and significant relation with infestation with r-value 0.406% during 2008-09.

The impact of chemical plant factors showed that the variety US-133 showed maximum nitrogen and fat contents with 1.147% and 2.20%, respectively. The highest

recovery was recorded to be 11.74% in variety US-312, whereas the lowest in SPF-234 which was 8.12%. The CPF-246 possessed maximum Phosphorous quantity (0.244%), whereas minimum contents were found in US-1491 (0.191%). The concentration of Potassium was comparatively higher in SPF-234 with 0.243% while concentration of Potassium was lower in CPF-237 with 0.188%. Maximum quantity of Calcium was calculated in variety US-1491 (0.249%). The maximum Magnesium-contents were found in variety SPF-234 (0.240%). Maximum Copper was recorded in variety CPF-237 (4.25ppm) while lowest Ferrous was recorded in US-312 (31.70ppm). The minimum Manganese recorded in US-312 (30.73ppm) while maximum Zinc present in SPF-234 (22.60ppm). The maximum percentage of Brix was recorded in US-312 (23.43%) and the varieties SPF-234 showed minimum percentage 18.46%. The POL percentage in US-312 was higher 20.93% while SPF-234 showed minimum POL percentage 15.27%. The variety US-718 showed maximum 15.84% of CCS while variety SPF-234 showed minimum percentage of CCS 11.08%. The maximum fiber contents were found in US-676 (13.68%) while US-1491 showed minimum percentage of fiber contents 11.99%. The recovery 11.74% and 11.52% was maximum in US-312 and US-718 while the variety SPF-234 showed minimum percentage of recovery 8.12%.

The maximum leaf area 466 cm^2 recorded in variety SPF-234 and the variety US-824 showed minimum leaf area 318 cm^2. The maximum leaf sheath hairiness 102 cm^2 was recorded in CPF-246 and variety SPF-234 showed minimum leaf sheath hairiness 53 cm^2. The maximum leaf thickness 0.660mm was found in variety CPF-246 while the variety CPF-237 showed minimum leaf thickness 0.583mm. The maximum plant girth 5.4 cm^2 in variety US-824 and the variety CPF-246 showed minimum plant girth 4.37 cm^2.

Studied regarding to chemical control revealed that minimum increase infestation was10.22% after the treatments with Furadan followed by Thimet, Padan and Monomehypo which showed 11.35%, 12.45% and 13.84%. Maximum infestation (26.13%) was observed in control treatment. In case of biological control the minimum infestation 9.31% was recorded by installing (40,000) *Trichogramma* eggs cards followed by (48000), (60000) and (72000) with infestation percentage 13.60%, 17.75% and 19.44%. The maximum infestation was recorded in control treatment (25.95%). The minimum infestation (16.57%) was observed after 10 days intervals followed by 15 and

20 days interval with 17.14% and 17.52%. In cultural and mechanical control the minimum infestation (12.91%) was recorded by using Trash mulching while maximum infestation (25.71%) was recorded in control. The use of detrashing showed (14.09%) infestation followed by Propping, Egg collecting and light traps with 15.69%, 16% and 16.84% respectively. The infestation was maximum (17.08%) after 20 days intervals while it was minimum (16.84%) after 10 days intervals.

Studies regarding to integration of various controls revealed that the minimum infestation (8.71%) was recorded by using the integration of *Trichogramma* cards + Detrashing + Light traps followed by 8.92%, 9.34% and 9.74% infestation by using the integration of *Trichogramma* cards + light Traps, *Trichogramma* cards + detrashing and detrashing + chemical control. The integration of *Trichogramma* cards + chemical control + light traps showed 10.46% infestation which significant different from the integration of *Trichogramma* cards + detrashing + chemical control, Chemical control + light trap + detrashing with infestation 11.66% and 11.86%. The integration of *Trichogramma* cards + chemical control with 12.39% did not showed significant difference from the integration of detrashing + light traps with 12.82%.The maximum infestation was observed in control treatment (25.45%). The minimum infestation 11.66% was recorded after 10 days interval followed by 15 days interval 12.21% while maximum infestation 12.53% was observed after 20 days interval

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