INTERFERENCE OF HORSE PURSLANE (*Trianthema portulacastrum* L.) WITH MAIZE (*Zea mays* L.) AT DIFFERENT DENSITIES

BY

MUHAMMAD SAEED

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(Muhammad Saeed)

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Muhammad Saeed
Department of Weed Science, Faculty of Crop Protection Sciences
NWFP Agricultural University Peshawar-Pakistan

ABSTRACT

Horse purslane (*Trianthema portulacastrum* L) a member of family Aizoaceae is a common weed in a host of crops such as maize, soybean, sugar cane vegetables and cotton in Pakistan and elsewhere. In order to quantify the impact of *Trianthema portulacastrum* on maize, experiments were conducted at Agricultural Research Farm, NWFP Agricultural University Peshawar, Pakistan for two crop seasons, *viz.* 2006 and 2007, using open pollinated variety "Azam". The experiments were laid out in a Randomized Complete Block design with split plot arrangements, having, three replications per treatments. Four maize plant spacing (15, 20, 25 and 30 cm) were kept in main plots, while weed densities (3, 6, 9, 12, 15 and 18 m^{-2}) were allocated as sub-plots. Data were recorded on days to 50% tasseling, days to 50% silking, days to maturity, plant height (cm), numbers of ears $plant^{-1}$, rows ear^{-1}, kernels ear^{-1}, ear weight (g), 1000-kernel weight (g), maize leaf area index, biological yield (t ha^{-1}), grain yield (t ha^{-1}), harvest index (%) and weed (*T. portulacastrum*) biomass (t ha^{-1}). All growth parameters except for the number of ears $plant^{-1}$ and rows ear^{-1} were affected by planting season, plant spacing and weed density. Plant spacing of 15 cm produced higher grain yields of 2.85 and 2.66 t ha^{-1} compared with 2.30 and 2.08 t ha^{-1} in wider plant spacing of 30 cm for the planting seasons of 2006 and 2007, respectively. However, for both years, yield components like ear weight and kernels ear^{-1} of individual plants were reduced with parallel decrease in plant spacing. Similarly, weed-free control plots produced higher grain yields of 3.04 and 2.87 t ha^{-1} *vis-a-vis* the grain yields of 2.14 and 2.0 t ha^{-1} in plots having weed density of 18 plants m^{-2} in 2006 and 2007, respectively. Plant spacing of 15 cm also resulted in higher biological yields of 6.96 and 6.69 t ha^{-1} in comparison with 30 cm spacing producing 5.92 and 5.85t ha^{-1} in 2006 and 2007, respectively. In the same vein, control plots had biological yields of 7.28 t ha^{-1} and 7.09 t ha^{-1} as compared with 5.81 t ha^{-1} and 5.65 t ha^{-1} in plots having weed density of 18 plants m^{-2} in 2006 and 2007, respectively. Plant spacing of 15 cm resulted in lower fresh weed biomass of 0.91and 0.88 t ha^{-1} compared with plant spacing of 30 cm producing higher weed biomass of 1.33 and 1.21t ha^{-1} in the growing seasons of 2006 and 2007, respectively. Likewise, the lower weed density of 3 plants m^{-2} resulted in lower weed biomass (0.97 t ha^{-1} in 2006 and 0.93 t ha^{-1} in 2007) compared with higher weed density of 18 plants m^{-2} (1.55 t ha^{-1} in 2006 and 1.49 t ha^{-1} in 2007). Decreasing plant spacing and increasing weed density of *T. portulacastrum* delayed tasseling, silking and maturity of grains. The *T. portulacastrum* infestations in plots having 3, 6, 9, 12, 15 and 18 plants m^{-2} resulted in yield losses of 4.2, 11.1, 18.6, 20.4, 27.2 and 29.5 % in 2006. The parallel figures for 2007 were 9.3, 14.3, 18.3, 23.2, 25.1 and 30.2 % in 2007. The two years of research showed that narrow spacing enhanced the competitive ability of maize crop and suppressed weed growth which eventually resulted in higher yields. *Trianthema portulacastrum* was a strong competitor to maize, and its infestation may inflict substantial yield losses, although the competitive ability was dependent on plant spacing and weed density. Plant spacing alone was not effective in suppressing *T. portulacastrum*; therefore, other cultural practices should also be integrated with optimum spacing to reduce the yield losses in maize crop.

Key words: *Trianthema portulacastrum*, weed competition, maize.

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I. INTRODUCTION

Agriculture being the backbone of Pakistan's economy employs 50% of the total labor force at national level, contributing 25 and 85% to GDP and export earnings, respectively. Maize is the third main cereal crop after wheat and rice in Pakistan, and second after wheat in North West Frontier Province (NWFP). Maize is a short-day annual, cross-pollinated, extensively used for food, feed and fodder in Pakistan (PARC, 2007). Owing to its significance in industries and food, maize requirements are increasing rapidly. The area under maize cultivation in Pakistan and NWFP was 1016.9 K and 516.1K ha, with production of 3088.4 K tonnes and 918.6 K tonnes, and the average yields of 3037 and 1780 kg ha^{-1} in Pakistan and NWFP, respectively (MINFAL, 2007). The maize average yield in Pakistan is low compared with other maize-producing countries of the world like USA, Canada, France, Argentina and China with the respective yields of 8.92 t ha^{-1}, 7.82 t ha^{-1}, 7.14 t ha^{-1}, 6.47 t ha^{-1} and 4.85 t ha^{-1} (FAO, 2003).

There is always competition for resources among crop and weeds, and such competition is mostly won by weeds as they are better adapted to different agro-ecological environments than the commercial crops. Weeds compete with crops for space, sunlight, moisture and nutrients thus decreasing crop yields. The competiveness of a crop is affected by plant spacing, leaf size, plant height and time of emergence (Hamayun, 2003), while weed competitiveness is dependent on weed species density and duration. The season-long weed competition caused considerable yield losses in maize (Dalley *et al*., 2006). In NWFP, the losses due to weeds in maize are *ca*. 20-40% (Anon 2005). In another study, weeds are reportedly capable of reducing corn grain yield by 35–70% if not managed (Ford and Pleasant, 1994) and uncontrolled weed growth brings about 83% decline in average grain yields of maize (Usman *et al*., 2001).

Horse purslane (*Trianthema portulacastrum* L) a member of family Aizoaceae, is a common weed of maize, soybean and cotton (Henty & Pritchard, 1975). It is a common weed of maize, cotton and vegetables all over Pakistan (Hashim and Marwat, 2002). Elsewhere in Pakistan, *T. portulacastrum* is a major weed in maize, cotton, potato, sugarcane, and summer vegetables and blooms from May-October. Due to indeterminate habit, vegetative and reproductive growth continues for the entire life span (Nayyar *et al*., 2001). Horse purslane is well established in Malaya, Western Asia, Africa, tropical America, Australia, India and several other countries (Mahajan, 1982). The weed favors moist or seasonally dried up wetlands, saline places and waste areas, blooms from May-November in India, turns into most aggressive weed of maize crop (Gill *et al*., 1978). Out of 69 weed species *T. portulacastrum* was realized as the most aggressive weed of maize crop (Kumar and Singh, 1983). Gupta and Mukerji (2001) also reported *T. portulacastrum* as a noxious weed posing considerable competition with maize crop (Gidnavar, 1979). At a density of 12 plants m^{-2} of *T. portulacastrum* gave lower maize yield of 3.54 t ha^{-1} than weed-free plots 3.89 t ha^{-1} (Ansar *et al*., 1996), and infestation can lead to 32.3% losses in maize crop (Balyan and Bhan, 1989).

Optimum plant spacing, particularly in fields infested with weeds is one of the key factors to reduce weed infestation and achieve high yield through shading the soil. Decreasing plant spacing decreased grain yield $plant^{-1}$ of maize but increased the total grain yield per unit area (Nafziger, 1996**.** Total yield was greater under narrow plant spacing but the yield of individual plant was higher under wider plant spacing (Randhawa, 1995). Maize kernel weights, ear weights and leaf area declined with decreasing plant spacing (Sajid, 2003). Wider spacing among plants improved growth and yields of single plant but did not compensate the total yield obtained from narrow plant spacing (Thakur *et al.,* 1997). Moreover, with a decrease in space between plants, leaf area, ears weight and number of kernels were decreased but leaf area index and grain yield ha^{-1} was increased (Johnson and Wilman, 1997). Therefore, suitable plant spacing is one of the key factors for enhancing maize competiveness, weed suppression ability and achieving high grain yield.

Keeping in view the aggressiveness of *T. portulacastrum* in maize crop, experiments were designed with the following objectives:

a) To determine the appropriate plant spacing of maize crop for suppression of *T. portulacastrum*.
b) To assess the effect of different densities of *T. portulacastrum* on yield and yield components of maize.
c) To evaluate the crop-weed interactions between maize crop and *T. portulacastrum*.

II. REVIEW OF LITERATURE

The following review on maize plant spacing was done through web browsing of world digital libraries, internet and other available literatures on the subject.

2.1 Plant spacing

Plant spacing is a principal factor for enhancing the crops competitive ability in crop-weed interference and is used as management practice for improving kernel and forage yield.

Maize kernel weights, ear weights, number of ears plant^{-1} and leaf area was declined due to decrease in plant spacing. The tasseling and maturity stages were also delayed at narrow spacing of 20 cm between plants compared to wider spacing of 40 cm (Sajid, 2003). Narrow plant spacing enhanced the grain yield and harvest index but prolonged tasseling, silking and maturity of maize crop (Waqar, 2002). Plant spacing of 15, 25 and 35cm were used in maize. Narrow plant spacing of 15 cm resulted in higher grain yield; however, the yield components plant^{-1} was higher at wider plant spacing of 35 cm. The plant height and leaf area index were also higher at 15 cm plant spacing (Randhawa, 1995). Wider plant spacing in maize increased most of the growth and yield components but did not compensate the total yield achieved in narrow plant spacing (Thakur *et al.*, 1997). Moreover, decreasing the space between plants declined total leaf area, ears weight and numbers of kernels of individual plant, but increased the leaf area index and grain yield on ha^{-1} (Johnson and Wilman, 1997). Similarly, reducing plant spacing in maize increased grain and biological yield but delayed grain maturation, however the number of ears plant^{-1} was not affected in any of the plant spacing (Naeem, 2004).

Four plant populations with 5, 6.25, 7.5 and 8.75 plants m^{-2} showed a linear increase in yield with increase in plant population (Strieder *et al.*, 2007). Higher plant population of 355552 plants ha^{-1} with decreased plant spacing provided higher biological yield ha^{-1} whereas, 44444 plants ha^{-1} with wider plant spacing provided higher kernel yield (Njoka *et al.*, 2004). In an another experiment maize yield improved with increasing plant populations by decreasing plant spacing and no yield decrease was noticed at the higher plant population. Kernel weight, ear weight, and leaf area plant^{-1} decreased with increasing plant populations. In spite of this, decrease in kernel and ear weights did not severely affect grain yield (Bruns and Abbas, 2003).

Three population densities of maize with 64000, 96000 and 128000 plants ha^{-1} were used for smothering velvetleaf growth and seed yield. Maize yield revealed a parabolic relation to population densities with a maximum of approximately 90000 plants ha^{-1} in one year, while a linear decline to increasing plant population densities under scarcity of moisture. Velvetleaf seed yield was decreased from 69 to 94% at the time when velvetleaf emerged with maize simultaneously. He concluded that plant population alone is not effective to suppress weed growth; therefore, other integrated weed management (IWM) practices should also be merged with higher plant population to reduce the yield losses in maize crop (Teasdale, 1998). The results of plant populations 65000, 130000 plants ha^{-1} on physiology and yield of maize was observed. Most of the maize parameters for example height, length of internode, height of ear and kernel moisture content were larger at low population, whereas leaf area $plant^{-1}$ was better at 65000 plant population ha^{-1} because of wide spacing between plants (Modarres *et al.*, 1998).

Tasseling, silking and maturity were delayed by higher plant population. The number of leaf $plant^{-1}$ and kernels ear^{-1} was not affected while number of ears $plants^{-1}$ was affected by higher plant density. Higher grain and biological yield was obtained from higher plant density (Amanullah *et al.,* 2009). Maize was planted at six densities (0.25, 3, 4.5, 6 and 9 plants m^{-2}), the lower density being considered as isolated density. Thus they obtained the higher grain and biological yield form 9 plants m^{-2}. Kernel yield $plant^{-1}$ and all other yield components decreased linearly as plant density increased (Hashemi *et al.,* 2005).

In maize crop decrease in spacing increased grain yield (Argenta *et al.*, 2001). Decreasing the soybean stand to 20, 40 and 60% in weed free plots showed average yield losses of 8, 18 and 34%, respectively. At the time when the weeds were there, percent yield decreased due to stand losses were at par with control plots. Weed competition and stand loss could mutually result significant yield losses in soybean. Weed development was not very much increased by decreasing competition as of soybean stand loss (Marwat and Nafziger, 1990). Low plant population resulted in lower kernel yield and more absorption of nitrogen, phosphorus and potassium compared to high plant density in four maize cultivars (Bavec and Bavec, 2002).

Four varieties (Azam, Sarhad, White, Pahari, and Shaheen) and five populations (80000, 100000, 120000, 140000 and 160000 plants ha^{-1}) were used. Maximum days to maturity were recorded in 160000 plants ha^{-1}. Maximum cob length, number of ears $plant^{-1}$, 1000-kernel weight, grain yield and biological yield were recorded in plots having 80000 plants ha^{-1} (Nasir, 2000). Plant densities of 50000, 100000 and 150000 plants ha^{-1} were used. They stated that the biomass and grain yield of the crop increased with increasing crop density **(**Akbar *et al.*, 1996). Plant populations of 5.56, 6.67, 8.33, and 11.33 plants m^{-2} were used, the optimum plant population density which resulted in the maximum grain yield was 11.33 plants m^{-2}. Grain number ear^{-1} and grain number row^{-1} were the most important grain components responding to changes in plant density (Dastfal *et al.,* 1999).

Plant density of 6, 9 and 12 maize plants m^{-2} was compared, the rate of change in relative growth among plant population was better at 9 and 12 plants m^{-2} compared to 6 plants m^{-2}. This response suggested that the physiological state of each plant at the beginning of the critical period had conditioned its reproductive fate. This early effect of plant type on final kernel number $plant^{-1}$ seemed to be exerted through current assimilate partitioning during the critical period Maddonni and Otegui (2004). If plant population increased from 44,460 to 74,100 plants ha^{-1}, grain yield per plant of corn decreased (Nafziger, 1996). Similarly, the effects of spacing and weeding were determined on maize kernel yield, weed biological yield and seed yield in rainfed environment. Maize kernel yield decreased from 16 to 35 % with increase in maize population from 74,100 to 103,740 plants ha^{-1}. The results of this study suggested that there was increased risk of a reduction in maize grain yield from competition for moisture and nutrients when row spacing is reduced below 90 cm and maize density increased above 74,100 plants ha^{-1}, making it difficult to integrate these cultural practices for weed suppression, under semi-arid conditions (Fanadzo *et al.*, 2007).

The results of plant populations with 30000, 40000, 50000, 60000 and 70000 plants ha^{-1} on ear yield of different maize varieties were compared. The ears number improved up to 58,000 plants ha^{-1}. Husked ear length decreased linearly in both varieties with increasing plant population. However increasing plant population did not affect plant height as well as ear height (E-Silva *et al.,* 2007). Kernel yield improved by increasing plant population density due to less spacing between plants and increase in number of plants per unit area (Gozubenli *et al.*, 2003). The accumulation of dry-matter was increased at higher plant population density of 111,111 plants ha^{-1} and decreased by 83,333 plants ha^{-1}. The means of yield attributing traits were higher at lower plant population. Significant improvement in kernel yield was noticed in 83,333 plants ha^{-1} because of wider plant spacing which improved the moisture accessibility and increased all the parameters significantly (Singh *et al.*, 1997). Plant population density had a significant effect on the dry matter accumulation, absolute growth rate and absolute acceleration rate. Moreover the parameters like leaf area index enhanced considerably with increase in the plant population density due to decreased plant spacing (Berzsenyi and Dang, 2007). Maize crop with different row spacing and plant population affected a number of physiological characters, fodder yield and dry matter yield but did not increase the plant height. (Turgut *et al.*, 2005).

In summary of the above citations the variation of plant spacing is an option to enhance the competiveness and grain yield of maize. Plant spacing also affected the rate of dry matter accumulation and its partitioning between vegetative and reproductive sinks considerably. Plant spacing alteration in maize affected all the growth and yield attributing traits. Optimum plant spacing in maize is necessary for producing more leaf area, taller plant height to capture sunlight and to enhance competitiveness, to suppress the weed growth. Cultural practices decrease the reliance on the chemical weed control, which is not only hazardous to human beings but also creates resistance in weeds. Thus, environment friendly management practices should be searched to decrease the reliance on herbicides and optimum plant spacing is one of those practices.

2.2 Maize and weed competition

The performance of maize crop is affected by weeds competition. After thorough searching a number of references are cited below regarding maize competition with other weeds.

The rise in the growing population density of jimsonweed (*Datura stramonium*) dropped maize plant height, dry biomass $plant^{-1}$ and kernel yield of maize. The weed denseness had a more significant effect on the plant height and dry biomass $plant^{-1}$ of *Zea mays* than plant arrangement (Oljaca *et al.*, 2007). Maize ear weight, ear length, filled ear length, ear width, kernels row^{-1}, number of rows, kernel depth, kernel weight and kernel moisture were affected by giant ragweed (*Ambrosia trifida* L.) competition (Williams and Masiunas, 2006). In a competition between silverleaf nightshade (*Solarium elaeagnifolium*) and maize, the maize growth parameters including height, surface area of the leaves and dry matter accumulation were diclined by the occurrence of the weed. Extending the length of interference will decrease the growth and yield parameters. The total yield and the major yield components i.e. kernels ear^{-1} and the 1000-kernels weight was clearly affected negatively by *S. elaeagnifolium*. Total grain yield was turned down by 64% at the time when no weeds were controlled (Baye and Bouhache, 2007). Similarly, in another study high weed stress lowered leaf area, chlorophyll content and kernel yield in all genotypes 35 to 65 % (Chikoye *et al.*, 2008). Non-managed weeds caused 83.03% reduction in average kernel yield of maize (Usman *et al*., 2001).

Yield declined very severely due to broadleaf signal-grass *Brachiaria platyphylla*) interference at a density of 150 plants m^{-2} when the maize and weed emerged simultaneously as sympatrics. Maize had the capability to hold up broadleaf signal-grass occurrence till twenty eight days after sowing with no yield reduction in any treatment (Alford *et al.,* 2005). One weed control practice among twenty seven and fifty four days following maize appearance could be sufficient to pass up any decline in maize grain productivity (Salgado *et al.,* 2005).

Weed interfering and withholding applied nitrogen increased the time taken to 50 % silking. Results from this research showed that the effect of early nitrogen fertilization gave an aggressive nature to maize than weeds (Evans *et al.*, 2003). Maize kernel yield in season-long competition of Johnsongrass (*Sorghum halepanse*) decreased the yield by 88 % from rhizomes and 57 % from seeds compared to yield obtained from control treatments. Ear length of maize was extremely affected by Johnsongrass interference compared to 1000-kernel weight. Johnsongrass plants from rhizomes appeared early, grew quicker and formed larger fresh biomass compared to plants from seed. In spite of this, fresh biomass and stem number of johnsongrass plant^{-1} as of seeds or rhizomes were not affected by maize (Mitskas *et al.,* 2003). Grassy weed competition after 15 cm height decreased maize grain yield by 1.13 kg ha^{-1} (Hellwig *et al.*, 2002). Purple nutsedge decreased the growth of both maize as well as soybean. However, maize was highly vulnerable to purple nutsedge competition than soybean (Tuor and Williams, 2002).

Weeds deprived the maize from nitrogen. Nitrogen assimilated by the weed was negatively correlated to that in aerial biomass of corn at crop maturity, which in turn was positively correlated to kernel yield. Bermuda grass reacted to the increased crop shading in the most uniform crop planting by increasing the aerial biomass allocation (Fernandez *et al.*, 2002). Rajcan and Swanton (2001) believed that incorporation of early detection of neighbors through the FR/R ratio as a primary signal during the critical period for weed control opened a new approach for future studies on weed competition in maize. Maize (*Zea mays* L.) was planted in 2.1 m rows at a plant population of 16000 plants ha^{-1} and *D. stramonium* L. was planted at five densities in association with maize. In both seasons the germination and vigour of the produced weed seeds declined with increased weed-crop interference (Saayman, 2000).

Higher intraspecific competition was showed for maximum plant density because of lower leaf area, leaf and stalk biomass plant^{-1} compared to lower plant density. Kernel yields were higher at maximum compared to minimum plant density for all leaf orientations. High plant density produced 10 % maximum across row leaf orientation and 21% maximum with row orientation compared to Random. Uncontrolled *Rottboellia chinensis* competition declined maize plant height by 18 % than check plots. The research showed that season-long *R. chinensis* competition decreased maize grain yield by 33 % than season-long weed control treatment (Strahan *et al.,* 2000).

Barnyardgrass (*Echinochloa crusgalli*) density and seedling emergence in relation to maize, affected the magnitude of maize yield loss. Higher maize kernel yield loss is 26 to 35% for early emerging *E. crusgalli* and 6% yield loss occured from *E. crusgalli* seedlings emerging afterward V4 stage of maize growth. Changes in corn leaf area index at 50% silking reflected the level of barnyardgrass competition in corn (Bosnic and Swanton, 1997). Interference by *S. halepense* reduced corn biomass by approximately 50 % (Barchuk *et al.*, 1995). *C. suecicum* occupied available space more rapidly than *A. retroflexus*. *Zea mays* yields were affected more by *C. suecicum* than by *A. retroflexus*. Yield losses of maize increased as the proportion of *C. suecicum* plants in the mixture increased. *C. suecicum* plants which were seeded before the crop and those which were not removed until later than 32 days after crop emergence lowered the maize yield (Frantik, 1994).

Lamb's-quarters was the most competitive of the three weed species, and green foxtail was the least competitive at low densities and maximum yield loss at high weed density varied with weed species in corn (Weaver, 2001). Moreover, crop planting date and canopy density influence interactions between weeds and corn (*Zea mays* L.), in their experiments dominant weed species were barnyard-grass (*Echinochloa crus-galli* L.) common lambsquarters (*Chenopodium album* L.), common purslane (*Portulaca oleracea* L.), green foxtail (*Setaria viridis* L.), redroot pigweed (*Amaranthus retroflexus* L.), and velvetleaf (*Abutilon theophrasti*) at densities ranging from 95 to 256 plants m^{-2} (Williams and Lindquist, 2007). Corn yields were reduced 13% from10 giant foxtail plants m^{-1} of row. Corn dry matter at maturity was decreased 24 and 23% from 10 giant foxtail plants m^{-1} of row (Fausey *et al*., 1997). Giant foxtail seed germination was not affected by plant density. Increase in *S. faberi* density caused a linear decrease in maize grain yield. When giant foxtail was present at 13.1 m^{-2} caused 18% yield losses, while maize yield was decreased curvilinear with increase in *Chenopodium album* density (Beckett *et al.*, 1988). Increasing density of common lambsquarters prolonged maize maturity (Sibuga and Bandin, 1980). Maize maturity was delayed by *A. repens* infestations (Bandin and Buchholtz, 1967).

The critical period for johnsongrass control was determined to be between 3 and 6.5 weeks after corn emergence to avoid losses above 5% of yield produced by full-season weed-free corn (Ghosheh *et al*., 1996). Season-long weed interference reduced corn yields by 19 % (Johnson *et al*., 2007). Grain yield was dependent on the stage of weed control (Rizzardi *et al*., 2008). When weeds were controlled at early stage i.e. 35 days after sowing, the grain and stover yield was increased 92.7 and 57.4 % respectively, on pooled basis compared to weedy check (Mundra *et al*., 2003). Similarly, forage sorghum when used as a surrogate weed may reduce from corn yield from 10 to 50 % (Myers *et al*., 2005). More than one weeding usually provided yield gain of about 60 % compared to single weeding (Gacheru *et al*., 1993). Maximum reduction in crop growth rate (38 %), leaf area index (44 %) and grain yield (51 %) were occurred in full season weed-crop competition as compared with weed free crop (Maqbool *et al*., 2006).

2.3 *Trianthema portulacastrum* Linn. (Horse purslane)

Horse purslane is one of the most serious weeds of maize in NWFP (Pakistan) and severely affected yield. Some of the information about this weed is provided below.

In a survey it was noted that *T. portulacastrum* is a problematic weed in maize and vegetables throughout Pakistan (Hashim and Marwat, 2002). *T. portulacastrum* is a host for Sunflower necrosis virus (SFNV) (Lavanya and Ramiah, 2005). *T. portulacastrum* is an important weed in sugarcane field (Halimie *et al.*, 1994). Horse purslane was the main leading weed in fertilized treatments (Kandasamy and Bayan, 2000). *T. portulacastrum* is noxious weed, which spreads rapidly in maize fields (Gupta and Mukerji, 2001).

T. portulacastrum is mostly restricted to drier and warmer areas (Mahajan, 1982). Sixty nine weeds belonging to 27 families in maize fields were studied. Information on occurrence and frequency, distribution pattern, periodicity and density of weeds were studied. The importance value index of *T. portulacastrum* surpassed all the other weeds of maize (Kumar and Singh, 1983). Horse purslane interference adversely affected the growth and development of maize (Chandra and Sahai, 1979). *T. Portulacastrum* species grew better in garden soil under shady situations and in sandy soils with full sunlight (Kumar, 1980). *T. portulacastrum* emerged before crop germination thus caused severe competition to maize crop (Gidnavar, 1979).

A checklist of noxious weeds indicated *T. portulacastrum* as a problematic weed in maize crop in the area. The weeds reported by Shah *et al*. (2006) in maize fields were *Trianthema portulacastrum*, *Achyranthus aspera*, *Amaranthus hybridus*, *A. viridis*, *Convolvulus arvensis*, *Cynodon dactylon*, *Cyperus rotundus*, *Datura alba*, *Sorghum halepense* and *Tribulus terrestris* (Shah and Khan, 2006).

The germination percentage of *T. portulacastrum* was increased with heat treatment at 60 ^{o}C and through mechanical scarification (Gill *et al.*, 1983). Seed set stated at 20 to 30 days after sowing. Growth and development in the rainy days were high and thus becomes more aggressive (Balyan *et al.*, 1985). Moreover, eleven parameters of two *T. portulacastrum* L. biotypes under cultural situations having 7 sets of 5 replicates each in monocultures and mixed cultures were compared. The green form was dominant than red in its competitive capability. Maximum vegetative and reproductive biomass was noticed in both forms under shade which illustrated that both are shade loving species (Reddy and Rao, 1985). Decline in cortical layers number of the root, uniform covering, centric palisade tissue around midrib and the bladder like cells in leaf epidermis has allowed it to grow under wide ecological environments was observed. The varied environmental adjustments permit it to grow from mesophytic to xerophytic circumstances (Mahajan, 1982).

Higher seedling emergence of horse purslane occurred in June and July while quicker and vigorous growth was noticed in the rainy months. If the environment for growth is optimum, flowering and seed starts 20 to 30 days after sowing (Balyan and Bhan, 1986). Competitive effects of carpetweed (*Trianthema portulacastrum*) on maize, pearl millet (*Pennisetum americanum*), cowpea (*Vigna unguiculata*) and mungbean (*Vigna radiata*) were evaluated. The competitiveness was enhanced in cowpea followed by maize, pearl millet and mungbean. *T. portulacastrum* competition during the growing season declined the yield of all the crops. Mean yield declines were 22.4, 32.3, 44.6 and 66.1% for cowpeas, maize, pearl millet and mungbeans, respectively (Balyan and Bhan, 1989). *T. portulacastrum* do not shed the cotyledons till the juvenile plant. The seed germination is epigeal and seedlings are of phanerocotylar and Macaranga type. The cotyledons of the seedlings are contradictory and continue till the V10 to V12 stage (Banerjee and Mukherjee, 2001).

The effects of *T. portulacastrum* and nitrogen on the quality of maize were studied by using of 200 kg nitrogen ha^{-1} and weeding two weeks after crop emergence. Which caused maximum kernel starch of 68.92 % and kernel protein of 7.74 %, while use of 100 and 150 kg nitrogen ha^{-1} and weeding two weeks after crop emergence caused maximum kernel oil of 3.71 % (Randhawa *et al.*, 2002). Root competition was very serious with *T. portulacastrum* interference because single *T. portulacastrum* in two cotton plants were effective sufficiently to decline cotton root length by 59 % (Vivek *et al.*, 2003b).

T. portulacastrum, *Echinochloa crusgalli*, *Parthenium hysterophorus*, *Cynodon dactylon*, *Digera arvensis* and *Cyperus rotundus* were among the dominant weeds. Grain yield loss increased with the raising in the time period of interference and higher loss of 33 % appeared due to full season interference. The maximum kernel yield and yield attributing traits were found in the control treatments till harvest. The critical period of weed interference was from thirty to sixty days following sowing (Vivek *et al.*, 2003a).

Horse purslane resulted in substantial competition to maize crop (Gidnavar, 1979). Similarly, horse purslane at the rate of 12 plants m^{-2} caused minimum maize yield of 3544 kg

ha^{-1} compared to weed free treatments which resulted in 3891 kg ha^{-1} yield (Ansar *et al.*, 1996). Maize yield losses due to *T. portulacastrum* infestation usually range upto 32.3 % (Balyan and Bhan, 1989). The biological yield and net productivity of *T. portulacastrum* was higher therefore it enters in to real competition with the maize crop (Kumar and Singh, 1983). Yield losses at varying density of 10, 20, 40, 80 and 160 plants m^{-2} of *T. portulacastrum* indicated that yield was declined with each increment in *T. portulacastrum* density (Punia *et al.*, 2004).

2.4 Management of *Trianthema portulacastrum*

Various management practices are mentioned in the following citations for control of *T. portulacastrum*.

The effects of N and P (100, 125 or 150 % of the recommended N and P rate applied as fertilizer or 100 % of the recommended N and P rate applied as farmyard manure (FYM)) and weed management (intercultivation, application of atrazine and glyphosate applied alone or in combination, and atrazine + intercultivation) on the productivity of maize. *T. portulacastrum* was the major weed in the experimental site. Application of atrazine + intercultivation resulted in the lower weed dry matter and the higher crop dry matter at harvest, number of cobs, 1000-grain weight and grain yield. Application of 150 % recommended rate of NP resulted in the higher values of the crop parameters measured (Mundra *et al.*, 2003). Combined herbicide application and cultural control as weed control methods in spring maize was assessed. *T. portulacastrum* was the dominant weed species. Pre emergence applications of atrazine at 0.5 kg a.i. ha^{-1}, atrazine + alachlor, both at 0.5 kg a.i. ha^{-1}, and atrazine at 0.5 kg a.i. ha^{-1} combined with hand weeding at 45 days after emergence were the most effective weed control treatments in terms of weed density and weed dry weight (Devender *et al.*, 1998).

Biological control of *T. portulacastrum* through fungal pathogens, namely *Cercospora trianthema*e, *Fusarium oxysporum* and *Gibbago trianthemae* was reported (Aneja and Kaushal, 1998). Feeding preferences of Khaki Campbell ducks for weeds of rabi and kharif seasons were observed. Out of many weeds only *T. portulacastrum* was utilized by the ducks (Parshad, 2003). The management of weeds by solar heating of the soil by means of transparent polyethylene sheets was assessed. Higher soil temperature of 53 ^{o}C was noticed in plastic cover at five cm depth. Transparent polyethylene sheets mulching for one month declined the seeds of *T. portulacastrum* (Arora and Yaduraju, 1998).

The effect of tank mixtures with four broadleaf herbicides for possible improvement of broadleaf weed control was studied. Control of horse purslane was at least 90 % with either 79 g ha^{-1} CGA-277476 tank-mixed with acifluorfen, fomesafen, chlorimuron, or imazaquin. The addition of CGA-277476 to acifluorfen or fomesafen did not improve control over acifluorfen or fomesafen alone on any of the weeds evaluated (Palmer and Shaw, 2000). The performance of fluchloralin, pendimethalin, oxadiazon and paraquat for controlling weeds, particularly *T. portulacastrum*, in pure Berseem and Berseem + Raya mixture was noticed. Addition of Raya at 2.5 or 3.75 kg ha^{-1} not only increased significantly the green fodder yield of first and of total cuts but also smothered *T. portulacastrum*. Total green fodder yield under pre-plant application of fluchloralin 0.35 and 0.45 kg, pre emergence application of pendimethalin 0.2 and 0.3 oxadiazon 0.2 and 0.25 kg ha^{-1} being at par. Berseem sown under the disturbed soil conditions after killing emerged weeds with gramoxone at 0.20 kg ha^{-1} produced more fodder yield than in plots sown without disturbing (Walia *et al.*, 1991). *T. portulacastrum* is broad leaf weed and can be managed successfully by metolachlor @ 1 kg ha^{-1} with one hand weeding in soybean (Ganesaraja and Kanchanarani, 2003).

Pre-emergence application of 1.25 kg ha^{-1} alachlor a.i. + 0.375 kg ha^{-1}atrazine was effective against *T. monogyna* in fodder maize and gave the higher fodder yields of 41.8 to 43.77 t ha^{-1} as compared to 32.7 to 33.95 t ha^{-1} without weed control (Gil *et al.*, 1978). Giant pigweed (*T. portulacastrum*) growing in sorghum (S. *bicolor*) was controlled in the seedling stage by atrazine (2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine) at a rate of 0.14 kg ha^{-1}, but plants 5 cm in diameter required a rate of 1.12 kg ha^{-1} (Rawson and Bath, 1981). Increasing sowing rates from 75 to 150 kg ha^{-1} for maize, 30 to 60 kg ha^{-1} for cowpeas and 37 + 15 to 75 + 30 kg ha^{-1} for maize/cowpeas mixture markedly decreased the dry weight of *T. monogyne* growing in these crops and increased their fresh fodder and dry matter yields (Brar *et al.*, 1984).

Post-emergence application of cyanazine @ 3 kg ha^{-1} controlled *T. portulacastrum* and gave 4.416 t grain ha^{-1}, 1000-grain weight of 2.54 g compared with 3.634 t ha^{-1} and 2.02 g, respectively for untreated plants. Manual weed control gave the greater leaf area at tasselling and grain numbers per ear however none of the treatments had any significant effect on ear numbers per plant (Mahboob *et al.*, 1984). Simazine or atrazine at 1.0 kg ha^{-1} applied to maize gave better control of *T. portulacastrum* than 2,4-D amine, 2,4-D ester or the lower rate of the 2 triazine herbicides in terms of weed numbers and dry matter m^{-2}. Higher average maize grain yields were achieved with 0.5 kg simazine ha^{-1} (4.14 t ha^{-1}) or hand hoeing (4.19 t ha^{-1}) (Yadav *et al.*, 1985). Atrazine applied at 0.5 kg ha^{-1} pre emergence to maize gave more effective weed control than hand weeding 3 and 5 weeks after sowing. Grain yields with manual control or atrazine were 4.51to 5.65 and 4.95 to 5.42 t ha^{-1}, respectively compared with 3.4 to 3.82 t ha^{-1} without weed control. This increase could be attributed to a larger number of cobs $plant^{-1}$, grains cob^{-1} and 1000-grain weight (Balyan and Bhan, 1987). Balyan (1989) also examined atrazine @ 0.5 kg ha^{-1} and two hand weedings at 3 and 5 WAS minimized the dominant weeds like *T. portulacastrum* and E. *colonum* as compared to weedy check. The above two weed control practices resulted in statistically similar growth and reproduction of pearl millet to that obtained under weed-free situations and significantly better than weedy conditions in both the years (Balyan and Bhan, 1988). Four post-emergence herbicides for control of horse purslane (*T. portulacastrum*) were studied. Fomesafen controlled horse purslane most effectively when applied at the two-branch stage of horse purslane in mung bean. Combinations of haloxyfop, fluazifop, or sethoxydim with fomesafen applied at the five-branch stage of horse purslane gave best weed control (Balyan and Malik, 1989). *T. portulacastrum* L. emerged along with crop seedlings developed rapidly and pose severe competition to pearl millet in first 30 days of crop growth. Weeding either manual (20 and 30 DAS) or chemical (atrazine 0.5 kg ha^{-1} pre emergence) decreased the density and dry weight of weeds and improved the plant height, height and yield attributes of pearl millet over weedy check. Late weeding (50 DAS) was of no use (Verma *et al.*, 1989).

In field trials on five post-emergence herbicides single or in mixture for management of *T. portulacastrum* in peanuts was evaluated. It was noticed that acifluorfen @ 0.3 kg ha^{-1}, pyridate+2,4-DB @ 1.0 + 0.3 kg, lactofen @ 0.2 kg and acifluorfen+bentazon @ 0.3+0.6 kg managed the weed more than 75%, as observed twenty six days after treatment. Pyridate only @1.0-2.1 kg did not manage *T. portulacastrum* effectively (Grichar, 1993). The effects of 2,4-D ester and Sodium salt both @ 0.5 to 1.5 kg ha^{-1}, used 20 to 30 days after sowing for the management of horse purslane in *Oryza sativa* was studied. The herbicide treated plots declined the *T. portulacastrum* density from check plots values of 4.86. The ethyl ester of 2,4-

D was found to be highly excellent in managing horse purslane than Sodium salt, Both formulations used twenty days after sowing gave maximum management of horse purslane than values got when they were used after a month (Tiwari and Jain, 1993). Field trial on the pre-plant use of trifluralin @ (0.5 and 0.75 kg ha^{-1}) and pre-emergence use of pendimethalin @ 0.5 kg ha^{-1} for controlling horse purslane was conducted. The seed yield was increased upto 10.1 and 36.9 % than hand hoeing and un-weeded check, respectively. Low grain yield were achieved by pre-emergence use of metolachlor @ (0.5 and 0.75 kg ha^{-1}) and isoproturon @ (0.56 and 0.75 kg ha^{-1}), while these herbicides were unsuccessful in providing an excellent management of horse purslane which was the main infesting weed (Brar and Walia, 1995).

2.5 Allelopathic effect of *Trianthema portulacastrum*

Reports showing the allelopathic effect of *T. portulacastrum* to inhibit crop emergence and growth are summarized.

Maize, tomato, pepper and radish seed germination and vogour were declined by the aqueous extracts of hors-purslane (Paneque *et al*., 2004). Root and shoot length of rice were declined by various aqueous concentrations of horse purslane extracts (Kim *et al.,* 2005). The autotoxic effect of horse purslane by soaking the stems, leaves, roots and total *T. portulacastrum* plant in water for twenty four hours was noticed. Under greenhouse, the aqueous extracts were applied to pots in which the *T. portulacastrum* seeds were sown. Extracts of stem, leaves and total plants resulted in decreasing the *T. portulacastrum* germination about 24.2 to 28.7 % after seven days of sowing. Shoot length declined from 9.5 to 9.8cm after thirty days of sowing. However, root extracts increased the length upto 10.6cm but declined the vigor index from 73.5 to 107.3 (Velu *et al*., 1994). Moreover, the allelopathic effect of various parts of *T. portulacastrum* on *Boerhaavia diffusa* which is a dicot weed and mostly found in gardenlands was observed. The leaf and total plant extract severely affected the *Boerhaavia diffusa* germination, dry matter accumulation and vigor after 7 days of germination; however at later stage of development, the toxic causes of *T. portulacastrum* were less probably due to the dilution of harmful compounds. The toxicity may be because of the non-phenolic substances of *T. portulacastrum* (Velu and Ali, 1995).

The allelopathic effects of *T. portulacastrum* extracts having 1-20 % aqueous stem, leaf, seed and total plant on the soybean seed germination, seedling vigor and yield was studied. Results showed that all extracts severely affected germination and growth of soybean. The leaf extracts possessing the higher effect (1 to 20 %) leaf extracts declined the seedlings germination from 9 to100 %, root growth from 38 to 91 % and shoot growth from 20 to100 %. The extracts mixed with soil did not affect the seed germination and biomass; however few yield traits and crop yields were declined by soil incorporation of these extracts. The duration of residue incorporation showed significant results, incorporation for one month declined kernel yield from 12.7 to 17.7 % and for three months 5.1 to 8.9 %, respectively (Umarani and Selvaraj, 1996).

III. MATERIALS AND METHODS

3.1. Layout and locality

The experiment was laid out in Randomized Complete Block design with a split plot arrangements, having three replications for each treatment at Agricultural Research Farm (71° 27′ and 72° 47′ E and 33° 40′ and 34° 31 N) and at an altitude of 335 m above sea level, NWFP Agricultural University Peshawar-Pakistan in 2006 and 2007. The soil was loamy with less than 1 % organic matter (Table 3.1). The treatment had four rows, 4 m long, with row to row distance of 0.75 m. The details of the treatment were as under.

3.2. Treatments

A. Maize plant spacing (Main plot)

15 cm spacing

20 cm spacing

25 cm spacing

30 cm spacing

B. *T. portulacastrum* density m^{-2} (Subplot)

0 Plants m^{-2} (check plot)

3 Plants m^{-2}

6 Plants m^{-2}

9 Plants m^{-2}

12 Plants m^{-2}

15 Plants m^{-2}

18 Plants m^{-2}

3.3. Experimental details

The seed of local variety “Azam” and *Trianthema portulacastrum* was planted on June 10, 2006 and June 12, 2007 using dibbler. Three seeds of maize and five seeds of *T. portulacastrum* were sown and then after germination thinning of maize and weed was done to achieve the desired density. All other weeds were removed manually from the maize crop throughout the growing season. In addition a separate nursery of maize and *T. portulacastrum* was also maintained for transplanting to compensate for failure of germination, if any. However, no germination failure took place, hence nursery was not utilized.

3.4. Fertilizer application

A basal dose of 150 kg ha^{-1} nitrogen and 60 kg ha^{-1}phosphorus was applied in the form of urea and single super phosphate. All the phosphorus and half of the nitrogen were applied prior to sowing whereas the remaining half nitrogen was applied as broadcast with first irrigation.

3.5. Irrigation

After two weeks of sowing, first irrigation was given to the experimental field. Succeeding irrigations were applied according to the field requirement.

3.6. Harvesting

Harvesting was done manually with the help of sickle.

3.7. Observations and Procedures

The following parameters were recorded during the course of experiments.

3.7.1. **Days to 50 % tasseling**

Data on days to tasseling were recorded when more than 50 % plants had developed tassels in each treatment. Days were counted from date of sowing till the completion of more than 50 % tassels.

3.7.2. **Days to 50 % silking**

Number of days taken to silking was counted from date of sowing to the time when half of the plants had silked.

3.7.3. **Days to maturity**

Days to maturity data were recorded by counting the number of days from date of sowing to the date of physiological maturity in each treatment.

3.7.4. **Plant height (cm)**

Ten plants were randomly selected from each subplot and the height was measured from ground level to the top of the plant at physiological maturity and averaged.

3.7.5. **Number of ears $plant^{-1}$**

Data on maize number of ears $plant^{-1}$ were recorded by randomly selecting ten plants from each subplot after harvesting. The numbers of ears was counted and then averaged.

3.7.6. **Ear weight (g)**

The data on ear weight were recorded by selecting ten ears from each treatment randomly. The ears were dried and weighed by means of electronic balance and then averaged.

3.7.7. **1000-kernel weight (g)**

Five samples were taken at random from the seed lot of each subplot, 1000-kernels were counted by seed counter and weight with the help of electronic balance. Average values of the samples were then determined

3.7.8. **Number of rows ear^{-1}**

Ten ears in each subplot were randomly selected after harvesting, kernel rows were determined in each ear separately and then average was calculated.

3.7.9. **Number of kernels ear^{-1}**

The total number of kernels in each ear was counted after threshing each ear individually in already randomly chosen ten ears and then averaged.

3.7.10. **Leaf area index**

LAI is the ratio of leaf surface (one side only) to the ground area occupied by the crop. The mean maize leaf area plant^{-1} of maize was multiplied by the respective maize density (plants m^{-2}) to get the maize leaf area index (Hussain, 2008).

3.7.11. ***T. portulacastrum* biomass (t ha^{-1})**

Weed biomass at crop harvest were measured by removing all *T. portulacastrum* plants from each subplot, weighed and subsequently the data was converted to t ha^{-1}.

3.7.12. **Biological yield (t ha^{-1})**

Two central rows in each subplot were harvested at maturity for measuring biological yield (ear + stover). Bundles were tied, air-dried, weighed by spring balance and converted into t ha^{-1} (Khan, 2008).

3.7.13. **Grain yield (t ha^{-1})**

Two central rows in each subplot were harvested, dried, shelled and weighed. The grain yield (kg) obtained after threshing was then converted into t ha^{-1} by the following formula (Khan, 2008):

$$\text{Grain yield (t ha}^{-1}\text{)} = \frac{\text{Grain yield (kg)} \times 10000}{\text{Area harvested (m}^{2}\text{)} \times 1000}$$

3.7.14. **Harvest index (%)**

Harvest index was calculated by applying the following formula (Hussain, 2008):

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \times 100$$

Analysis of the data

Combined analyses were carried out for each parameter of the two years data, using the ANOVA procedure (Appendix-A). The effect of growing season was significant**;** therefore, the analyses on effect of growing season were performed (Appendix-B). The details of meteorological data are presented in Table 3.2. Analyses of variance were performed and significant means were separated using Least Significant Difference test (Steel and Torrie, 1980**).** Since treatments were quantitative, spaced at equal intervals, therefore, regression analyses were carried to determine the trends for the relevant parameter(s).

Table 3.1. Physio-chemical properties of the soil 2006 and 2007

Characteristics	**Units**	**2006**	**2007**
Clay	%	35.0	36.0
Silt	%	49.3	49.1
Sand	%1	5.7	5.90
Soil Texture	class	loam	loam
Soil Organic Matter	g kg^{-1}	0.81	0.79
Total Soil Nitrogen	g kg^{-1}	0.039	0.039
Lime ($CaCO_3$)	%	14.4	15.1
Ec (1:1)	d S m^{-1}	0.87	0.86
pH (1:1)		8.17	8.19

Source: Department of Soil and Environmental Sciences, NWFP Agricultural University Peshawar-25130, Pakistan

Table 3.2. Meteorological data for the growing seasons of maize crop in 2006 and 2007

		Temperature (°C)				
Year	Month	Mean Max	Mean Min	R. Humidity	Precipitation (mm)	
2006	May	38.6	22.3	35.9		11.9
	June	38.9	23.4	45.0		20.2
	July	34.3	24.6	68.6		85.1
	August	35.0	22.2	72.8		46.6
	September	32.5	21.1	61.5		4.00
	Average	**35.9**	**22.7**	**56.7**	**Total**	**167.8**
2007	May	36.6	20.5	55.2		27.0
	June	41.6	26.3	52.9		00.0
	July	41.1	28.8	68.4		00.0
	August	38.2	26.5	67.1		20.2
	September	33.7	23.1	62.7		22.0
	Average	**38.2**	**25.0**	**61.3**	**Total**	**69.2**

Source: Weather Station, Pakistan Forest Institute, Peshawar-25130, Pakistan

IV. RESULTS AND DISCUSSION

4.1. Days to 50% tasseling

The effect of plant spacing, weed (*Trianthema portulacastrum* L.) density and their interaction regarding days to tasseling of maize was significant (Appendix-B1). Narrow plant spacing of 15 cm took more days to tasseling (55 and 54) compared to wider spacing of 30 cm (52 days) in 2006 and 2007, respectively. However, 15 and 20 cm plant spacing were statistically at par with each other during both the years (Table 4.1). Delayed tasseling at narrow plant spacing may be due to lower soil temperature and higher humidity under the thick canopies compared to thin canopies in wider plant spacing. These results are in line with the findings of Hamayun (2003), who reported early tasseling in wider spacing of maize. Similarly, according to Naeem (2004), tasseling was delayed at narrow plant spacing.

In the growing season of 2006, control plots took less days (51) to tasseling, though statistically at par with weed density of 3 plants m^{-2} compared to weed densities of 15 and 18 plants m^{-2} took more days to tasseling (56 and 57). Similarly in 2007, early tasseling (51 days) was noticed in control plots, statistically at par with weed densities of 3, 6 and 9 plants m^{-2}. Whereas, weed density of 18 plants m^{-2} took more days (57) to reach tasseling stage (Table 4.1). Delayed tasseling at higher weed densities may be due to high interspecific competition. These results are in agreement with the work of Evans *et al.* (2003) who reported that weed interference prolonged days to tasseling of maize.

Regression analysis indicated that the effect of increasing density of *T. portulacastrum* was curvilinear in both years, except 15 cm plant spacing which showed linear response in 2006. Overall results showed that tasseling was enhanced in wider plant spacing, may be due to because of less competition. These results are in agreement with the findings of Waqar (2002) who reported that narrow plant spacing delayed the tasseling in maize. Beckett *et al*. (1988) reported that late tasseling was associated with lower yield due to the less time available for the grain-fill period.

4.2. Days to 50% silking

Data pertaining days to silking were significantly affected by plant spacing in the growing season of 2006 and were not significantly affected in 2007; however, the effect of weed density and their interaction were significant in both years (Appendix-B2). As shown in Table 4.1, 15 cm plant spacing took more days to silking (63 and 61) compared to 30 cm plant spacing taking less days to silking (60 days) in 2006 and 2007, respectively. The early silking at wider plant spacing may be due to low humidity under thin canopies as compared to delayed silkng at narrow spacing. Similar results were reported by Sajid (2003), who reported that days to 50% silking prolonged with decreasing plant spacing. Similarly according to Modarres *et al*. (1998) and Oleksy *et al*. (2001); the silking was delayed by increasing plant population of maize due to decrease in spacing.

In the growing season of 2006, control plots took less days to silking (59) which was statistically at par with weed density of 3 plants m^{-2}, whereas higher weed density of 18 m^{-2} plots took more days to silking (63), again at par with plots having weed density of 12 and 15 m^{-2}. Similarly in 2007, less days to silking (59) were observed in maize monoculture (weed free plots) which was statistically similar to treatments having weed density of 3 and 6 m^{-2}. While more days to silking (61 and 62) were noticed at weed density of 15 and 18 m^{-2} (Table 4.1). The results are in line with the findings of Evans *et al*. (2003), who reported that development and growth of maize was affected by weed competition and increased the days taken to 50 % silking.

The regression analysis indicated that days to silking increased quadratically with increase in weed density in all plant spacing in both years (Fig. 4.2a & b). Sibuga and Bandeen (1980) reported that weed competition reduced the early growth of several crops including maize which showed delay in the silking stage of the crop. Similarly, Beckett *et al*. (1988) reported that late tasseling and silking were associated with lower yields because of the shorter time available for the grain filling period.

Table 4.1. Effects of maize plant spacing and *T. portulacastrum* density on days to 50% tasseling and days to 50% silking.

	Days to 50% tasseling YEAR		Days to 50% silking YEAR	
PLANT SPACING (S) (cm)	2006	2007	2006	2007
15	55.0 a	54.1 a	62.5 a	60.7
20	53.9 ab	53.3 ab	62.0 ab	60.3
25	53.0 bc	52.3 b	60.7 bc	59.9
30	52.1 c	52.0 b	60.4 c	59.5
LSD $_{(0.05)}$	1.71	1.36	1.56	NS
T. portulacastrum DENSITY (D) (m^{-2})				
0	51.1 e	50.8 d	59.3 d	58.5d
3	51.6 de	51.2 d	59.8 d	59.2cd
6	52.3 cd	51.7 d	61.3 c	59.4cd
9	53.2 bc	52.1 cd	61.6 bc	59.5c
12	54.1 b	53.3 c	62.3 ab	60.8b
15	55.7 a	54.9 b	62.7 a	61.1ab
18	56.5 a	56.5 a	63.0 a	62.1a
LSD $_{(0.05)}$	1.06	1.37	0.95	0.90
INTERACTION (S x D)	*	*	*	*

Means followed by same lowercase letters in a column for each parameter and for each year are not significantly different at $p \leq 0.05$ (LSD tests).

S = Maize Plant Spacing (cm)
D = *T. portulacastrum* Density (m^{-2})

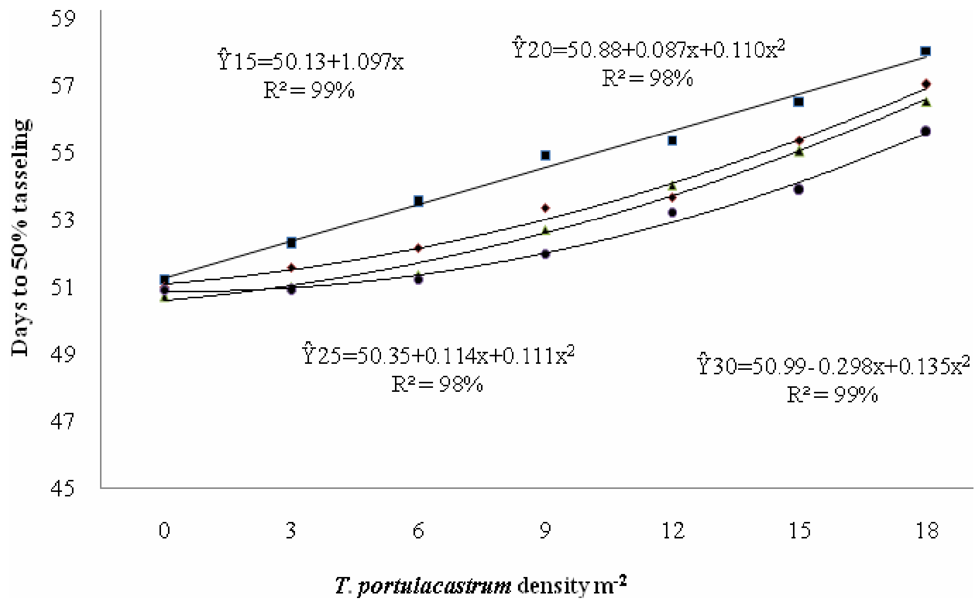

Fig. 4.1a. Interactive effects of maize plant spacing and *T. portulacastrum* density on days to 50% tasseling in 2006 (■ = 15, ♦ = 20, ▲= 25, ● = 30 cm).

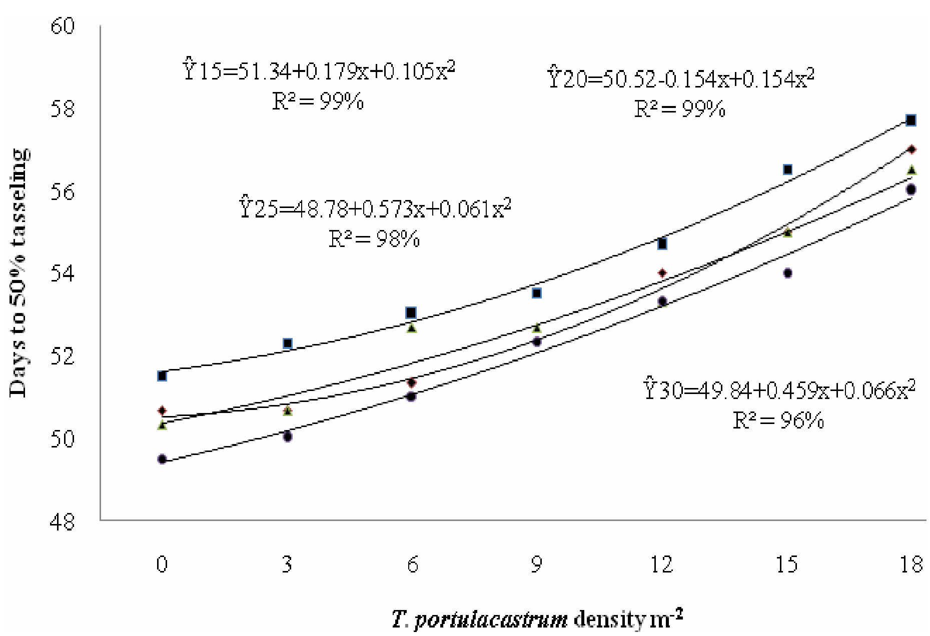

Fig. 4.1b. Interactive effects of maize plant spacing and *T. portulacastrum* density on days to 50% tasseling in 2007 (■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

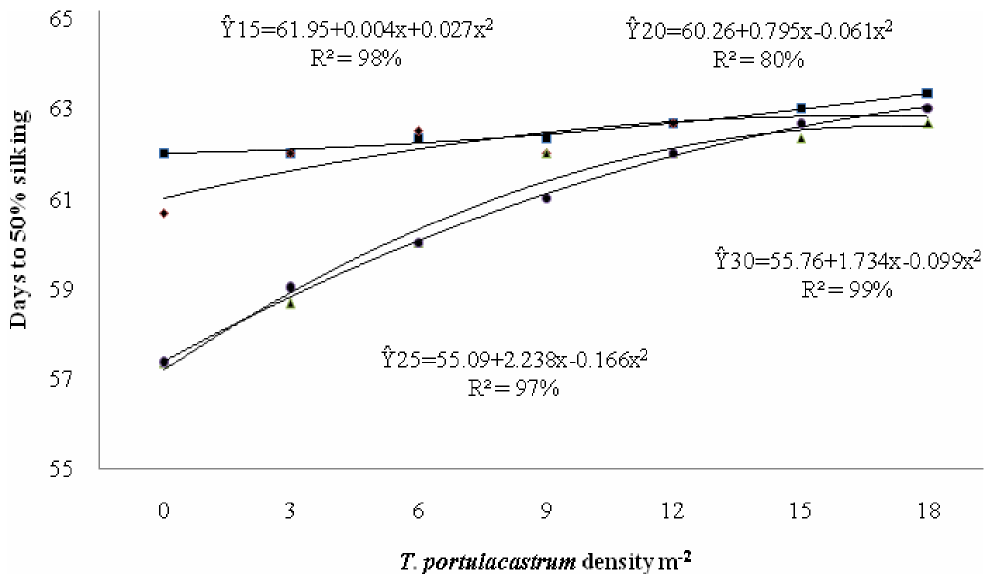

Fig. 4.2a. Interactive effects of maize plant spacing and *T. portulacastrum* density on days to 50% silking in 2006 (■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

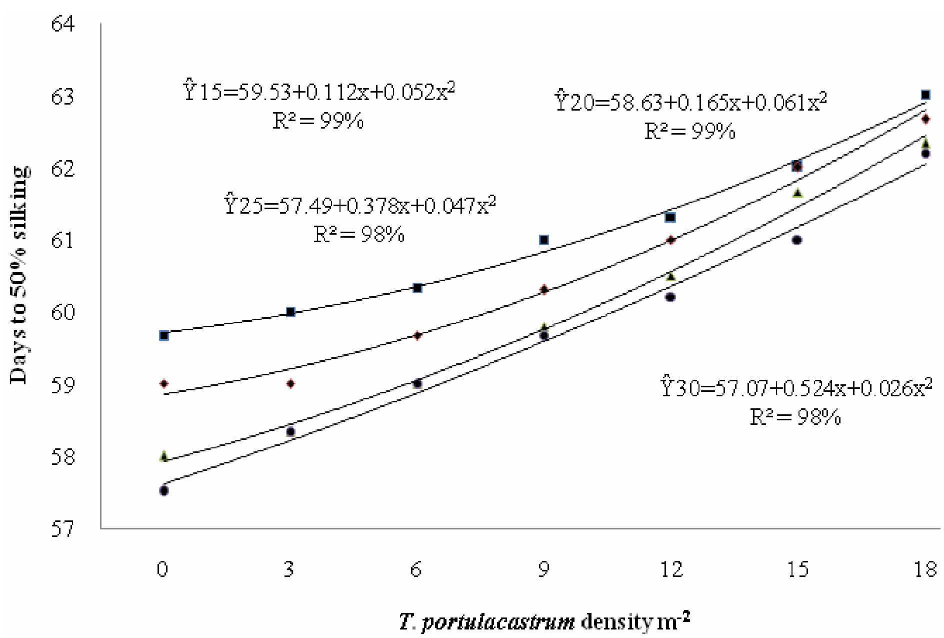

Fig. 4.2b. Interactive effects of maize plant spacing and *T. portulacastrum* density on days to 50% silking in 2007 (■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

4.3. Days to maturity

The effects of plant spacing, *T. portulacastrum* density and their interaction during both years on days to physiological maturity of maize were significant (Appendix-B3). More days (94 in 2006 and 93 in 2007) were recorded in 15 cm plant spacing compared with (92 days in 2006 and 2007 both) in 30 cm plant spacing. However, plant spacing of 15 cm was statistically at par with 20 cm spacing, whereas plant spacing of 30 cm was at par with 25 cm spacing (Table 4.2). According to Hamayun (2003) and Waqar (2002) decreasing plant spacing prolonged the maturity of maize crop.

Among the weed density, check plots took less days to physiological maturity (92 in 2006 and 91 in 2007); however, it was at par with plots having 3 plants of *T. portulacastrum* m^{-2}, whereas 6 and 9 weed densities were also at par with each other in both years. Similarly, higher weed density of 18 m^{-2} resulted in 95 and 94 days to physiological maturity in the growing seasons of 2006 and 2007, respectively (Table 4.2). Thus increasing weed density delayed maturity of maize which may be due to competition for resources. The results are in line with the findings of Sibuga and Bandeen, (1980), who found that *Chenopodium album* L. delayed maize maturity. Similar results were also reported by Evans *et al*. (2003) that physiological maturity of maize was delayed by weed interference. Black *et al*. (1996) reported that soybean maturity was delayed by presence of *Sesbania exaltata*. Regarding plant spacing x *T. portulacastrum* density interaction, the *T. portulacastrum* free plots took lesser days to maturity in 15, 20, 25 and 30 cm plant spacing and more days at higher weed density of 18 plants m^{-2} by 15 cm plant spacing interaction.

Regression analysis revealed that the number of days to maturity increased with increasing weed density in all plant spacing (Fig. 4.3a & b). The overall response was quadratic during both years except in 20 and 25cm plant spacing which showed linear trend in 2007. The weed density beyond 12 plants m^{-2} showed maximum delay in maturity. Overall results indicated that increasing weed density delayed the maturity of maize.

4.4. Plant height (cm)

The effect of plant spacing on plant height of maize was not significant while effect of *T. portulacastrum* density and their interaction with plant spacing was significant in both years (Appendix-B4). As the plant spacing decreased from 30 to 15 cm, the maize plant density increased, thus causing more competition for light which ultimately led to increase the plant height. Randhawa (1995) agreed with the results that plant height of maize increased with decreasing plant spacing. Similarly, higher plant density resulted in maximum plant height and yield compared to lower plant density (Bavec and Bavec, 2002).

In the growing season of 2006, taller plant height (179.5 cm) was noticed in control plots which were at par with plots having a weed density of 3 m^{-2}, while shorter plant height (162.2 cm) was observed in plots having weed densities of 18 m^{-2}, again statistically similar to a weed density of 15 m^{-2}. Similarly in 2007, maximum plant height (176.8 cm) was noticed in check plots which however, was statistically similar to lower weed density of 3 plants m^{-2}. Minimum plant height (157 cm) was recorded in plots having a weed density of 18 m^{-2} which was at par with 12 and 15 weeds m^{-2}. Generally there was a linear decrease in plant height of maize with each increment in weed density due to increase in competition for resources. According to Oljaca *et al.* (2007) *Datura stramonium* L. interference decreased maize plant height, dry biomass $plant^{-1}$ and grain yield. The results are also in line with Williams and Lindquist (2007), Young *et al*., (1999) and Evans *et al.,* (2003) who reported that maize plant height declined with increasing weed density.

Regression analysis showed quadratic decrease in plant height across the plant spacings in 2006, while in 2007, 25 and 30 cm spacing plant height was linearly decreased with increasing weed density while effect of 15and 20 cm was quadratic (Fig. 4.4a & b). According to Moti *et al*. (1994) and Williams and Masiunas (2006) weed interference decreased maize plant height.

Table 4.2. Effects of plant spacing and *T. portulacastrum* density on days to maturity and maize plant height.

	Days to maturity YEAR		Plant height (cm) YEAR	
PLANT SPACING (S) (cm)	2006	2007	2006	2007
15	93.9 a	92.8 a	172.0	167.2
20	93.1 ab	92.8 a	171.6	165.3
25	92.5 b	92.4 ab	170.5	164.9
30	92.2 b	91.8 b	169.4	164.0
LSD $_{(0.05)}$	1.12	0.72	NS	NS
T. portulacastrum DENSITY (D) (m^{-2})				
0	91.5 e	90.8 f	179.5 a	176.8 a
3	91.7 e	91.3 ef	176.8 ab	171.3 ab
6	92.1 de	91.8 de	175.4 b	168.7 b
9	92.7 cd	92.3 cd	170.4 c	165.8 b
12	93.3 c	92.8 bc	168.1 c	158.9 c
15	94.3 b	93.5 b	163.8 d	159.0 c
18	95.0 a	94.4 a	162.2 d	157.0 c
LSD $_{(0.05)}$	0.69	0.76	3.81	6.33
INTERACTION (S x D)	*	*	*	*

Means followed by same lowercase letters in a column for each parameter and for each year are not significantly different at $p \leq 0.05$ (LSD tests).

S = Maize Plant Spacing (cm)
D = *T. portulacastrum* Density (m^{-2})
NS = Non Significant

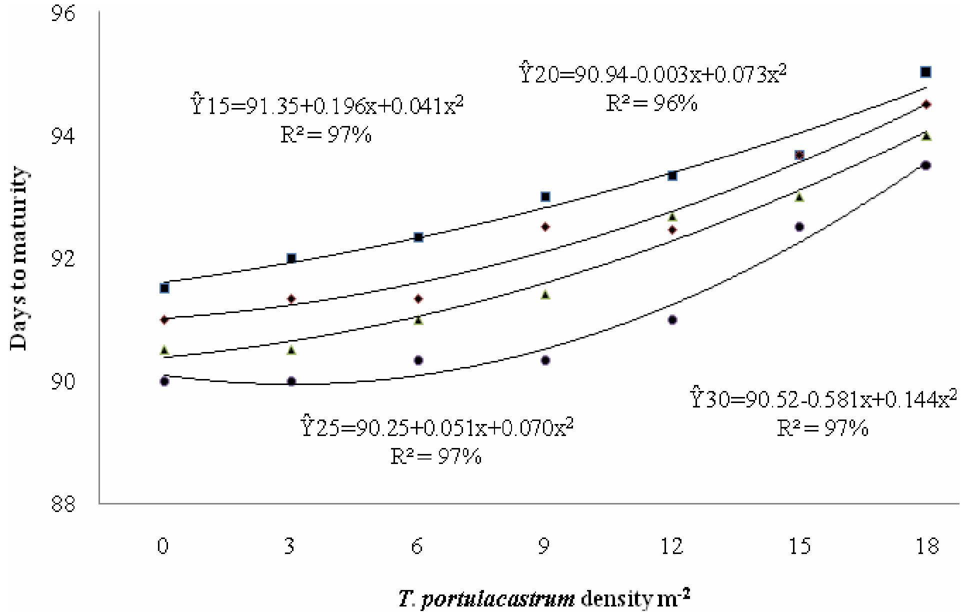

Fig. 4.3a. Interactive effects of maize plant spacing and *T. portulacastrum* density on days to maturity in 2006 **(**■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

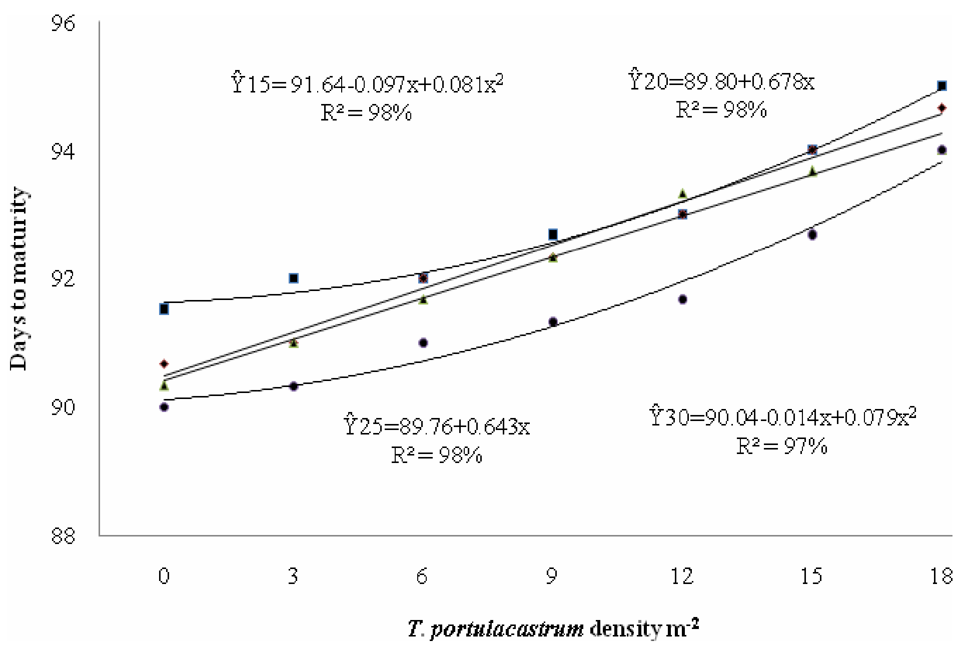

Fig. 4.3b. Interactive effects of maize plant spacing and *T. portulacastrum* density on days to maturity in 2007 **(**■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

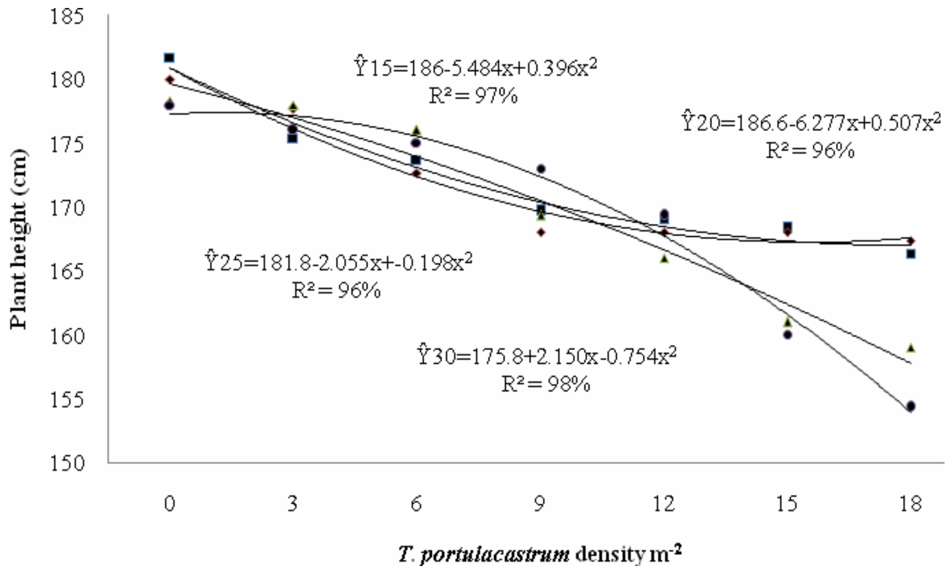

Fig. 4.4a. Interactive effects of maize plant spacing and *T. portulacastrum* density on maize plant height (cm) in 2006 (■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

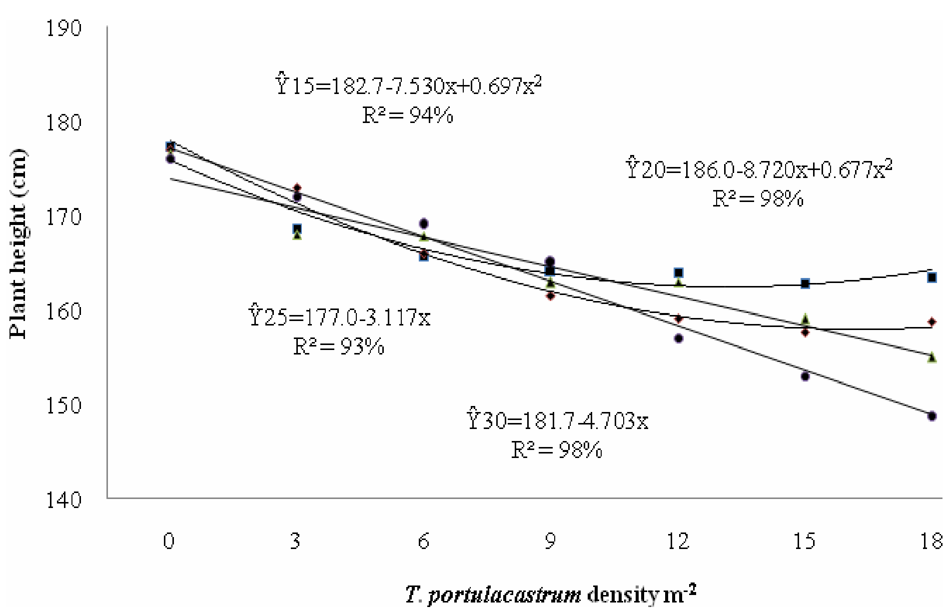

Fig. 4.4b. Interactive effects of maize plant spacing and *T. portulacastrum* density on maize plant height (cm) in 2007 (■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

4.5. Number of ears plant^{-1}

The effects of plant spacing, weed densities and their interaction were significant on number of ears plant^{-1} in both years (Appendix-B5). The results are in line with the work of Naeem (2004) that number of ears plant^{-1}of maize were increased in wider spacing between plants compared to narrow spacing as a result of having more space. Similarly according to Tyagi *et al*. (1998) lower plant population of 53,333 plants ha^{-1} produced more ears plant^{-1} as compared to high plant population of 88,888 plants ha^{-1}. Likewise, Turgut *et al,* (2005) reported that population density did not affect number of ears plant^{-1}.

Sayed and Sandi (1984) reported similar results that ears plant^{-1} of maize were not affected by weed infestation. However, delayed weed control caused a consistent reduction in the number of ears plant^{-1}. Similarly, the number of ears plant^{-1} did not change with increase in weed density (Sajid , 2003). On average all the maize plants produced single ear plant^{-1} (Randhawa *et al.,* 2002). In our findings the overall results are not significant; therefore, regression analysis was not performed on number of ears plant^{-1}.

4.6. Ear weight (g)

The effect of years on ear weight was variable, in 2006 ear weight was significantly affected by plant spacing while in 2007 the effect was not significant; however, weed densities and weed x spacing interaction was significant during both years (Appendix-B6). In the growing season of 2006, higher ear weight of 101 g was recorded in 30 cm plant spacing, which was at par with all other spacings except 15 cm, which showed lower ear weight of 96.4 g. In 2007, plant spacing did not affect ear weight significantly (Table 4.3). The results are in line with the work of Maqbool *et al*. (2006), that decreasing space between plants reduced ear weight of individual plant. In the same way Bruns and Abbas (2003) were of the view that decrease in ear weight was directly proportional to increase in plant density.

In the growing season of 2006, higher ear weight (105.3 g) was recorded in control plots as compared to weed density of 18 plants m^{-2} (93.2 g) which was statistically similar to weed density of

Table 4.3. Effects of maize plant spacing and *T. portulacastrum* density on number of ears plant^{-1} and ear weight.

	Number of ears plant^{-1} YEAR		Ear weight (g) YEAR	
PLANT SPACING (S) (cm)	2006	2007	2006	2007
15	1.01	1.00	96.4 b	90.4
20	1.02	1.01	98.2 ab	91.8
25	1.03	1.02	99.1 ab	92.9
30	1.04	1.02	101.0 a	94.0
LSD $_{(0.05)}$	NS	NS	3.00	NS
T. portulacastrum DENSITY (D) (m^{-2})				
0	1.04	1.03	105.3 a	101.7 a
3	1.04	1.03	103.3 b	98.0 ab
6	1.03	1.02	101.0 c	96.7 b
9	1.03	1.02	98.6 d	91.7 c
12	1.01	1.01	95.4 e	89.3 c
15	1.00	1.00	94.2 ef	85.1 d
18	1.00	0.98	93.2 f	83.3 d
LSD $_{(0.05)}$	NS	NS	1.88	3.82
INTERACTION (S x D)	NS	NS	*	*

Means followed by same lowercase letters in a column for each parameter and for each year are not significantly different at $p \leq 0.05$ (LSD tests).

S = Maize Plant Spacing (cm)
D = *T. portulacastrum* Density (m^{-2})
NS = Non Significant

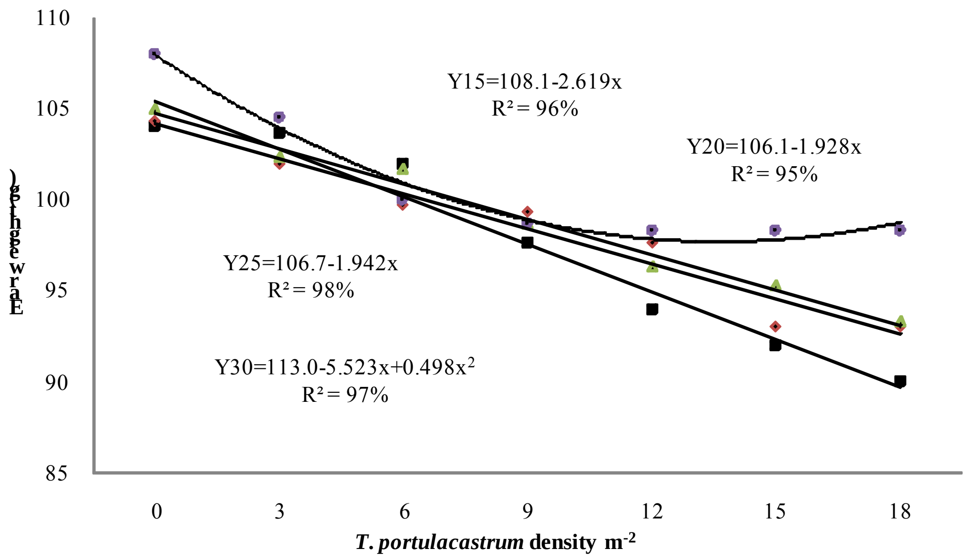

Fig. 4.6a. Interactive effects of maize plant spacing and *T. portulacastrum* density on ear weight (g) in 2006 **(**■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

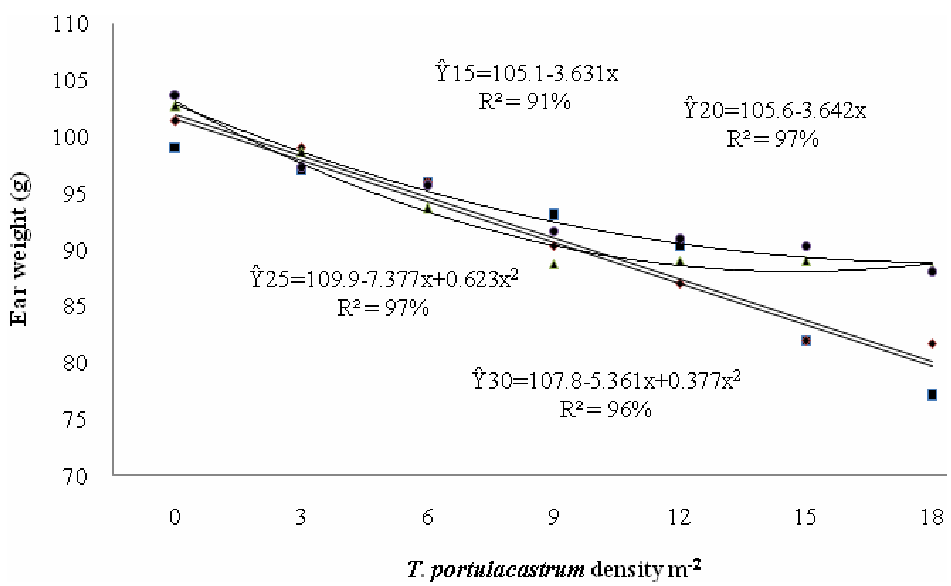

Fig. 4.6b. Interactive effects of maize plant spacing and *T. portulacastrum* density on ear weight (g) in 2007 **(**■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

15 plants m^{-2}. Similarly in 2007, maximum ear weight (101.7 g) was noticed in pure stands (weed free plots) of maize as compared to minimum ear weight (83.3 g) in higher weed density of 18 m^{-2}. The effects of other weed densities (3, 6 and 9, 12 m^{-2}) were at par with each other. The results are in agreement with the findings of Williams and Masiunas (2006), who reported that maize ear weight decreased significantly by *Ambrosia trifida* L. interference.

Ear weight decreased linearly at all plant spacings, except 30 cm plant spacing which showed quadratic trend in 2006. There was no further decrease in ear weight beyond 12 weed density in 30 cm plant spacing (Fig. 4.6a & b). In the growing season of 2007, the trend lines showed that ear weight was declined linearly by 15 and 20 cm and quadratically by 25 and 30 cm plant spacing. The decrease in ear weight is somehow similar up to 12 weed density in all plant spacings; however, beyond this density only 15 and 20 cm plant spacing affected the ear weight with increase in weed density due to increase in competition.

4.7. 1000-kernel weight (g)

As shown in Appendix-B7, 1000-kernel weight of maize was significantly affected by plant spacing and *T. portulacastrum* density, while their interaction was not significant in both years. Higher 1000-kernel weight (194.8 g in 2006 and 189.5 g in 2007) was recorded in wider spacing of 30 cm, compared to narrow spacing of 15 cm (188.3 g in year 2006 and 178.4 g in year 2007). Plant spacing of 20 and 25 cm were at par with each other during both years. The results indicated that 1000-kernel weight decreased with decrease in plant spacing. Bavec and Bavec (2002) also reported that kernel weight declined at higher plant densities with decreasing space between plants. Likewise, Tyagi *et al*., (1998) reported that 1000-kernel weight of lower maize plant population was high as compared to higher plant population. Similarly, Waqar (2002) found that kernel weight was directly proportional to plant spacing.

Among *T. portulacastrum* densities maximum 1000-kernel weight (201.1 g and 194.6 g in 2006 and 2007, respectively) was recorded in maize monoculture, which was statistically similar to lower weed density of 3 plants m^{-2} (196.6 g in 2006 and 189.6 g in 2007) in both years. The weed densities of 6, 9 and 12 were also at par with each other during both years. Minimum 1000-kernel weight of 183.4 and 173.8 g was recorded in plots having 18 plants of

T. portulacastrum m^{-2} in the growing seasons of 2006 and 2007, respectively. Lower weed density of 3 plants m^{-2} did not reduce 1000-kernel weight; however, higher density affected 1000-kernel weight due to both intra as well as interspecific competition. Regression analysis showed that 1000-kernel weight decreased linearly by increasing weed density in all plant spacing (Fig. 4.7a & b). According to Baye and Bouhache (2007) and Young *et al*. (1984) weed competition decreased 1000-kernel weight of maize. In another study the kernel weight of maize was considerably affected by giant ragweed (*Ambrosia trifida* L.) interference (Williams and Masiunas, 2006).

4.8. Number of rows ear^{-1}

The effect of plant spacing, weed density and their interaction for number of rows ear^{-1} in maize was non-significant in both the years (Appendix-B8). As shown in Table 4.4 the effect of all plant spacings was almost similar. In similar studies by (Randhawa, 1995 and Svecnjak *et al*., 2006) the number of rows ear^{-1} was not affected by plant spacing and plant population. In another study, intensified plant density increased plant height but slightly changed the number of rows ear^{-1} (Bavec and Bavec, 2002). In similar studies the number of rows ear^{-1} slightly decreased with increase in weed density and duration (Young *et al*., 1984). Weed interference affected grain weight cob^{-1}, thousand grain weight, number of grains cob^{-1} however, did not reduce the number of rows cob^{-1} (Randhawa, 1995). The number of rows ear^{-1} was not stimulated by weed interference (Williams and Masiunas, 2006).

Sine the overall results on number of rows ears^{-1}was not significant therefore regression analysis were not performed.

Table 4.4. Effects of maize plant spacing and *T. portulacastrum* density on 1000-kernel weight (g) and number of rows ear^{-1}.

	1000-kernel weight (g) YEAR			Number of rows ear^{-1} YEAR	
PLANT SPACING (S) (cm)	2006	2007		2006	2007
15	188.3 c	178.4 c		13.2	13.1
20	190.9 b	182.1 bc		13.2	13.2
25	192.1 b	185.0 b		13.3	13.2
30	194.8 a	189.5 a		13.3	13.3
LSD $_{(0.05)}$	2.06	4.14		NS	NS
T. portulacastrum DENSITY (D) (m^{-2})					
0	201.1 a	194.6 a		13.5	13.5
3	196.6 ab	189.6 ab		13.4	13.3
6	192.9 bc	186.6 bc		13.3	13.2
9	191.1 bcd	184.0 bcd		13.3	13.1
12	188.7 bcd	180.7 cde		13.2	13.1
15	186.9 cd	177.0 de		13.1	13.0
18	183.4 c	173.8 e		13.1	13.0
LSD $_{(0.05)}$	8.16	7.56		NS	NS
**INTERACTION (S x D)	NS	NS		NS	NS

Means followed by same lowercase letters in a column for each parameter and for each year are not significantly different at $p \leq 0.05$ (LSD tests).

S = Maize Plant Spacing (cm)
D = *T. portulacastrum* Density (m^{-2})
NS = Non Significant

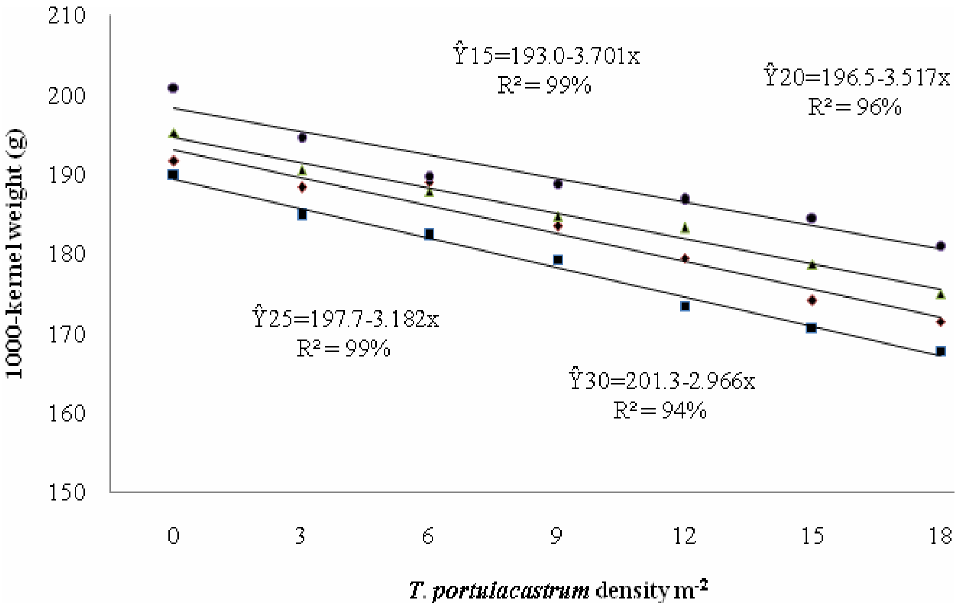

Fig. 4.7a. Interactive effects of maize plant spacing and *T. portulacastrum* density on 1000-kernel weight (g) in 2006 (■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

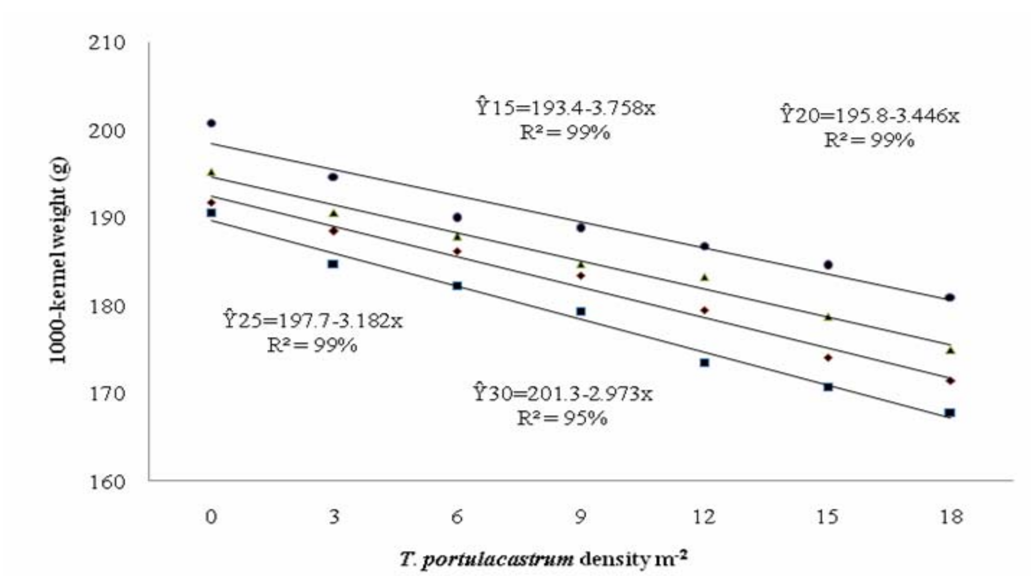

Fig. 4.7b. Interactive effects of maize plant spacing and *T. portulacastrum* density on 1000-kernel weight (g) during 2007 (■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

4.9. Number of kernels ear^{-1}

The effect of plant spacing, *T. portulacastrum* density and their interaction was significant for number of kernels ear^{-1} of maize in both years (Appendix-B9). Higher kernels ear^{-1} (319 and 309 in 2006 and 2007, respectively) were recorded in 30 cm plant spacing and less kernels ear^{-1} (292 and 268 in 2006 and 2007, respectively) were observed in 15 cm plant spacing, while 25 and 30 cm plant spacings were statistically at par in both years (Table 4.5). The results of two years data indicated that with increase in plant spacing, the number of kernels ear^{-1} increased, which may be due to availability of more space and nutrients. Similar results were reported by Tianu and Picu (1983) and Wang *et al.* (1987), that kernels ear^{-1} were reduced at higher plant densities, compared to lower density of maize crop. Similarly, the lower kernel yield was attributed mostly to decline in number of kernels row^{-1} and number of kernels ear^{-1} (Hashemi *et al.*, 2005). In the same way Tyagi *et al.* (1998) reported that lower plant population produced maximum number of kernels ear^{-1}, compared to higher plant population.

In case of weed density, the lower density of 3 plants m^{-2} did not cause significant reduction in number of kernels ear^{-1} compared with pure stands of maize in both years. The higher number of kernels ear^{-1} (323 & 308 during 2006 and 2007, respectively) was recorded in check plots and lower kernels ear^{-1} (282 & 269 during 2006 and 2007, respectively) was noticed in plots having higher weed density (18 m^{-2}) that was at par with density of 15 plants m^{-2} in both years. The decrease in kernels ear^{-1} with increasing weed density may be due to interspecific competition for nutrients. In competition study *Datura stramonium* L affected number of kernels ear^{-1} and 1000-kernel weight (Cavero *et al.*, 1999). Increase in weed density resulted in decrease of maize kernels ear^{-1} and consequently grain yield (Moti *et al.*, 1994). The decreasing trend in number of kernels ear^{-1} with increase in weed density was also supported by Anjum (2003).

Regression lines of two years data indicated that number of kernels ear^{-1} decreased linearly in all plant spacing except 15 and 20 cm plant spacing in 2006 which showed quadratic trend (Fig. 4.9a & b). Similar results are reported by Williams and Masiunas (2006) that all ear traits reduced with increasing giant foxtail density.

4.10. Leaf area index

Leaf area index was significantly affected by plant spacing and *T. portulacastrum* density and their interactions for both years were also significant (Appendix-B10). Maximum leaf area index (2.99 in 2006 and 2.93 in 2007) was recorded in 15 cm plant spacing and minimum leaf area index (1.41and 1.35 in 2006 and 2007, respectively) was recorded in 30 cm plant spacing (Table 4.5). Though the average leaf area plant^{-1} of maize increased with decrease in plant spacing yet the leaf area index decreased with decrease in plant spacing. The higher maize leaf area index at narrow spacing of 15 cm was attributed to greater number of maize plants per unit area. In a study maize kernel weight, ear weight and leaf area were declined with decreasing plant spacing (Sajid, 2003 and Johnson and Wilman, 1997). Similarly greater leaf area index under high plant population of maize was reported by Berzsenyi and Dang (2007).

Among the *T. portulacastrum* density, higher maize leaf area index (2.99 and 2.74 in 2006 and 2007, respectively) was recorded in weed free plots, while the lower maize leaf area index (1.79 in 2006 and 1.73 in 2007) was recorded in plots having the higher weed density of 18 m^{-2} (Table 4.5). The effect of 12 and 15 m^{-2} weed density was at par with each other in both years. The leaf area index of maize decreased with each increment in weed density due to increase in weed competition. The findings of Tollenaar *et al*. (1994) are similar, they found significant effect of weed competition on maize leaf area index and according to Williams and Masiunas (2006) weed interference decreased the leaf area index.

The trend lines showed that leaf area index of maize decreased linearly by *T. portulacastrum* in all plant spacings (Fig. 4.10a & b). The decreasing trend in leaf area index could be considered as the main factor that caused lower yield in many ways. Firstly total green area was reduced and thus enough food could not be supplied to the plants. Secondly total light interception was decreased and thirdly, the space was occupied by weeds. Weed competition reduced leaf area index of maize (Baye and Bouhache, 2007).

Table 4.5. Effects of maize plant spacing and *T. portulacastrum* density on number of kernels ear^{-1} and leaf area index.

	Number of kernels ear^{-1} YEAR			Leaf area index YEAR	
PLANT SPACING (S) (cm)	2006	2007		2006	2007
15	292 b	268 c		2.99 a	2.93 a
20	294 b	284 b		2.80 b	2.51 b
25	310 a	295 ab		2.57 c	1.93 c
30	319 a	309 a		1.41 d	1.35 d
LSD $_{(0.05)}$	10.9	14.9		0.15	0.17
T. portulacastrum DENSITY (D) (m^{-2})					
0	323 a	308 a		2.99 a	2.74 a
3	317 ab	303 ab		2.80 b	2.62 b
6	312 bc	297 bc		2.60 c	2.45 c
9	304 cd	291 cd		2.23 d	2.04 d
12	300 d	281 de		1.95 e	1.84 e
15	289 e	273 ef		1.85 ef	1.83 e
18	282 e	269 f		1.79 f	1.73 f
LSD $_{(0.05)}$	10.0	9.6		0.12	0.07
INTERACTION (S x D)	*	*		*	*

Means followed by same lowercase letters in a column for each parameter and for each year are not significantly different at $p \leq 0.05$ (LSD tests).

S = Maize Plant Spacing (cm)
D = *T. portulacastrum* Density (m^{-2})
NS = Non Significant

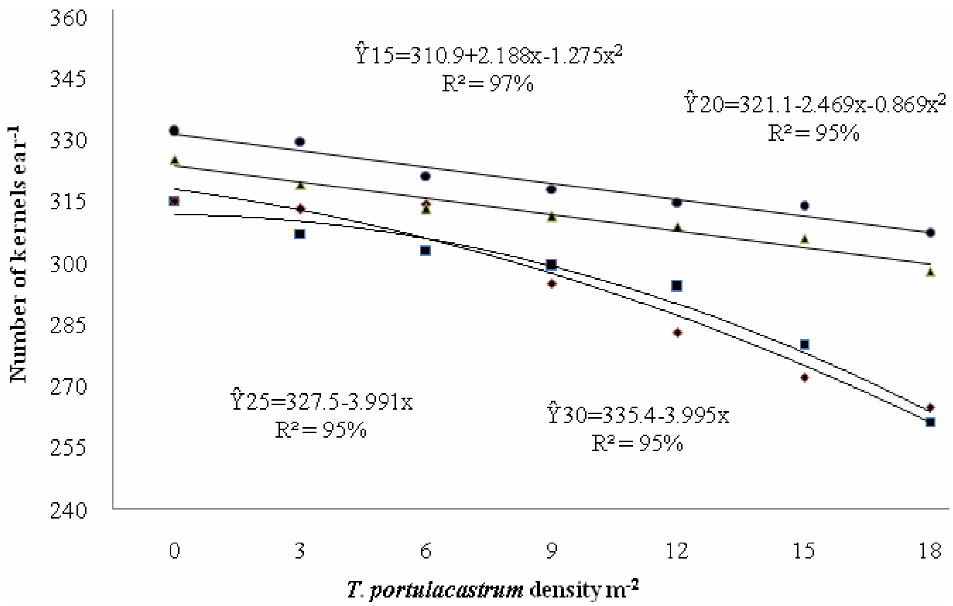

Fig. 4.9a. Interactive effects of maize plant spacing and *T. portulacastrum* density on number of kernels ear^{-1} in 2006 **(**■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

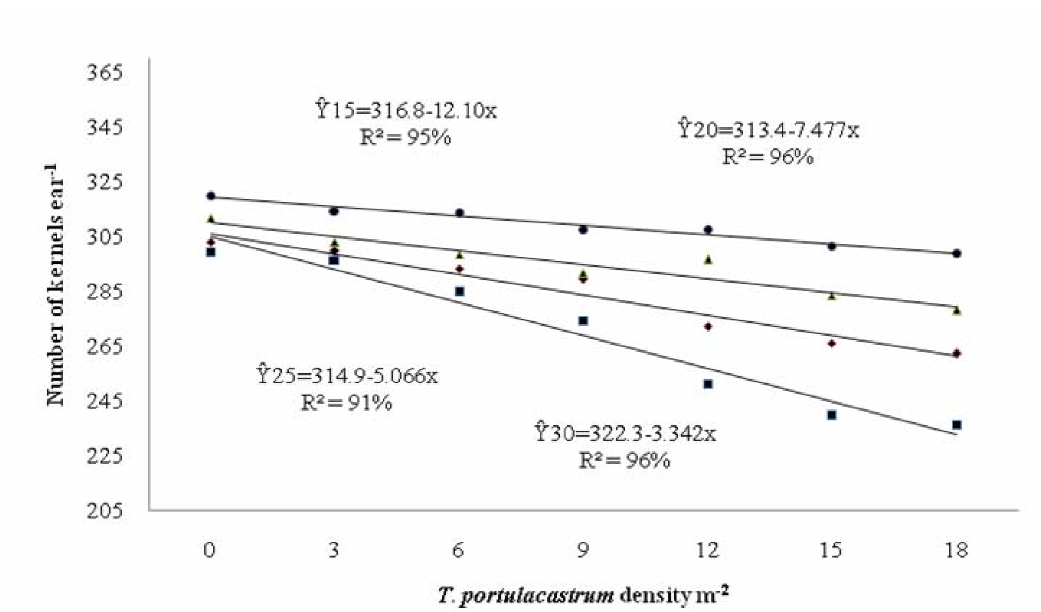

Fig. 4.9b. Interactive effects of maize plant spacing and *T. portulacastrum* density on number of kernels ear^{-1} in 2007 **(**■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

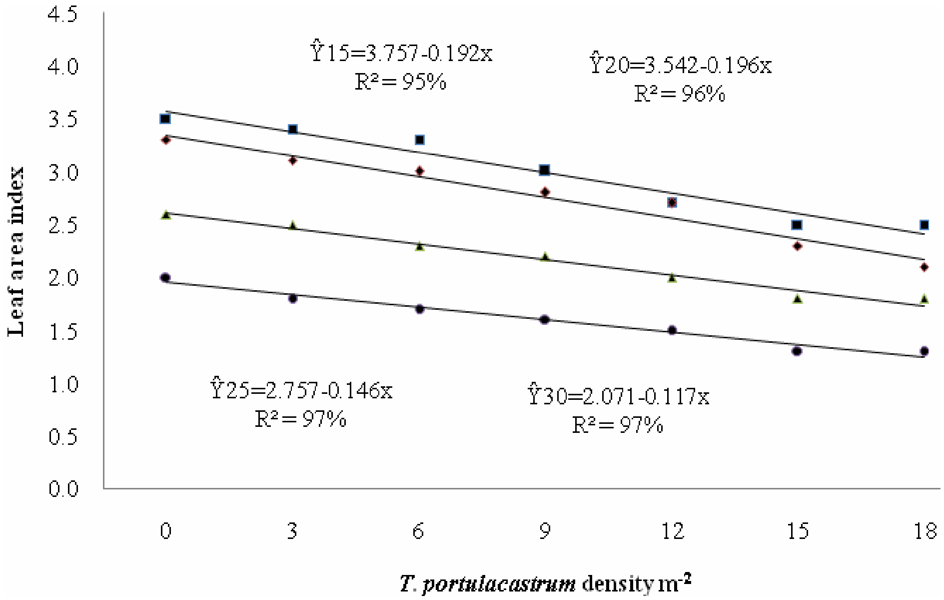

Fig. 4.10a. Interactive effects of maize plant spacing and *T. portulacastrum* density on leaf area index of maize in 2006 (■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

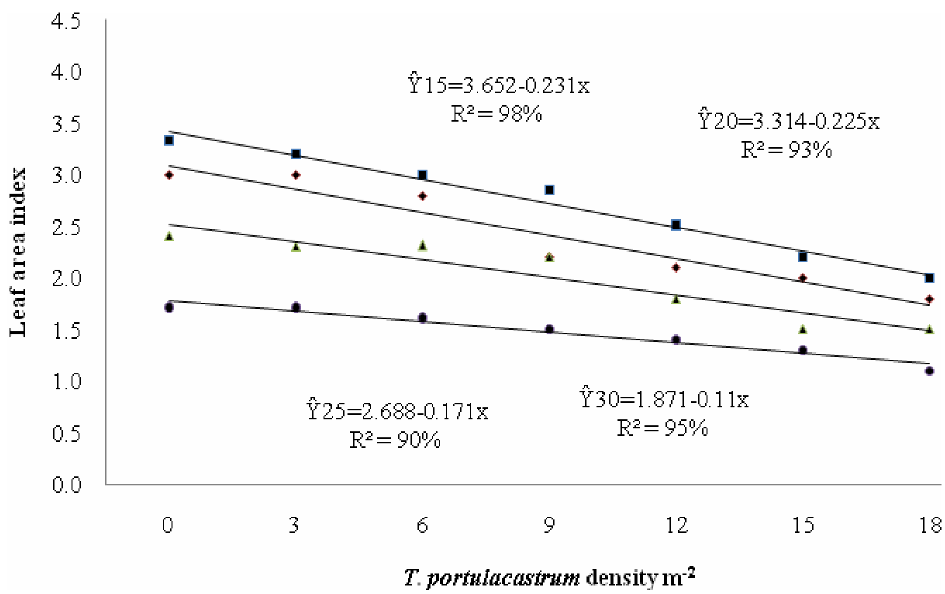

Fig. 4.10b. Interactive effects of maize plant spacing and *T. portulacastrum* density on leaf area index of maize in 2007 (■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

4.11. *Trianthema portulacastrum* biomass (t ha^{-1})

The data analysis) depicted that effect of plant spacing on fresh *T. portulacastrum* biomass was significant during both the years (Appendix-B11). As shown in Table 4.6 higher weed biomass (1.33 t ha^{-1}and 1.21 t ha^{-1}) was recorded in 30 cm plant spacing and lower biomass (0.91t ha^{-1} and 0.88 t ha^{-1}) was recorded in 15 cm plant spacing in the growing seasons of 2006 and 2007, respectively. Due to taller maize plants in 15 cm spacing (Table 4.2), the weed was shaded, as a consequence its overall growth was negatively affected (visually observed) which eventually resulted in minimum weed biomass in narrow plant spacing. Increasing plant population of maize declined the weed biomass (Tollenaar *et al*., 1994). According to Cavero *et al.* (1999) the development of maize leaf area plant^{-1} during the primary growth stage was quicker than *Datura stramonium* consequently growth of *D. stramonium* L. was suppressed. The faster growth of maize leaf area and height reduced the photosynthetically active radiation received by the weed and as a result suppressed the growth of weed, thus reducing space within crop plants and suppressed the weed growth and biomass (Maqbool *et al*., 2006 and Wilson *et al*., 1995).

The effect of weed density on the biomass of *T. portulacastrum* was also significant in both years (Appendix-B11). Maximum weed biomass (1.55 t ha^{-1} and 1.49 t ha^{-1} in 2006 and 2007, respectively) was recorded in plots having higher weed density of 18 m^{-2} and minimum (0.97 t ha^{-1}in 2006 and 0.93 t ha^{-1} in 2007) was recorded in plots having lower weed density of 3 m^{-2}. The increased in weed biomass with increasing weed density was due to increase in number of weeds per unit area, which are in line with findings of Moore *et al.*, (2004), who reported that more is the number of weeds, more is the biomass.

Plant spacing x *T. portulacastrum* density interaction for weed biomass was also significant in both the years (Appendix-B11). Regression analysis showed that weed biomass increased linearly in all spacing by increasing weed density (Fig. 4.11a & b). During both years narrow spaced plants of 15 cm suppressed the growth of *T. portulacastrum* due to enhancement in competitiveness which ultimately resulted in minimum weed biomass. In a weed-crop competition study Gaffer *et al.*, (1997) also reported that high crop density decreased weed biomass.

4.12. Biological yield (t ha^{-1})

The biological yield of maize was significantly affected by plant spacing and weed density; however, the interaction was not significant in both the years (Appendix-B12). Higher biological yield (6.96 t ha^{-1} in 2006 and 6.69 t ha^{-1} in 2007) was recorded in narrow spacing of 15 cm compared to lower biological yield (5.92 t ha^{-1} in 2006 and 5.85 t ha^{-1} in 2007) in wider spacing of 30 cm (Table 4.6). In a similar study maize biological yield increased with increasing plant density (Bruns and Abbas, 2003) and fodder yield was reportedly more under narrow spacing compared with wider spacing (Naeem, 2004). Moreover reducing space, enhanced the competitiveness of crop which resulted in higher crop biological yield (Anjum, 2003 and Acciaresi and Zuluaga, 2006).

In case of *T. portulacastrum* density, the higher biological yield (7.28 and 7.09 t ha^{-1} in 2006 and 2007, respectively) was recorded in check plots and lower biological yield (5.81 and 5.65 t ha^{-1} in 2006 and 2007, respectively) was recorded in plots having higher density of 18 *T. portulacastrum* m^{-2} (Table 4.6). According to Rao (2000) an increase of one kilogram of weed growth corresponds to a reduction of one kilogram of crop growth. With increasing density of weed the biological yield of maize decreased accordingly (Young *et al*., 1984 and Moti *et al*., 1994). Increasing jimsonweed density reduced plant height and biological yield of maize (Oljaca *et al*., 2007).

The regression analysis showed that during 2006, the biological yield of maize decreased quadratically at all plant spacing, except 15 cm plant spacing which showed linear trend. While during 2007, the narrow (15 cm) and wider plant spacings (30 cm) showed quadratic trend and 20 and 25 cm plant spacings showed linear decreased in biological yield with increase in weed density. (Fig. 4.12a & b). The trend lines depicted that at narrow spacing, the biological yield of maize was less affected by increasing weed density compared to wider spacing. This proved that maize plants competed well with *T. portulacastrum* at narrow spacing because of high maize density per square meter weeds were smothered which resulted in higher crop biological yield.

Table 4.6. Effects of maize plant spacing and *T. portulacastrum* density on *T. portulacastrum* biomas (t ha^{-1}) and biological yield (t ha^{-1}).

	T. portulacastrum biomas (t ha^{-1}) YEAR		Biological yield (t ha^{-1}) YEAR	
PLANT SPACING (S) (cm)	2006	2007	2006	2007
15	0.91 b	0.88 d	6.96 a	6.69 a
20	1.01 b	0.97 c	6.59 b	6.51 a
25	1.25 a	1.12 b	6.26 c	6.16 b
30	1.33 a	1.21 a	5.92 d	5.85 c
LSD $_{(0.05)}$	0.24	0.05	0.28	0.30
T. portulacastrum DENSITY (D) (m^{-2})				
0	---	---	7.28a	7.09 a
3	0.97 e	0.93 f	6.95b	6.73 b
6	1.14 d	1.06 e	6.67b	6.40 c
9	1.28 c	1.17 d	6.27c	6.29 cd
12	1.41 b	1.29 c	6.22c	6.02 de
15	1.51 ab	1.39 b	5.83d	5.94 e
18	1.55 a	1.49 a	5.81d	5.65 f
LSD $_{(0.05)}$	0.11	0.07	0.33	0.28
INTERACTION (S x D)	*	*	NS	NS

Means followed by same lowercase letters in a column for each parameter and for each year are not significantly different at $p \leq 0.05$ (LSD tests).

S = Maize Plant Spacing (cm)
D = *T. portulacastrum* Density (m^{-2})
NS = Non Significant

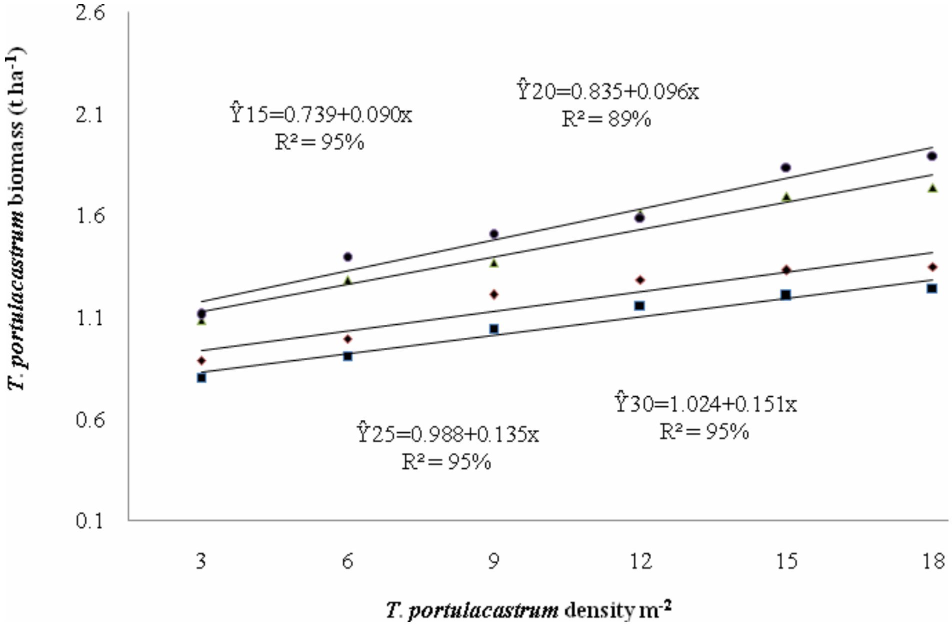

Fig. 4.11a. Interactive effects of maize plant spacing and *T. portulacastrum* density on *T. portulacastrum* biomass (t ha^{-1}) during 2006 (■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

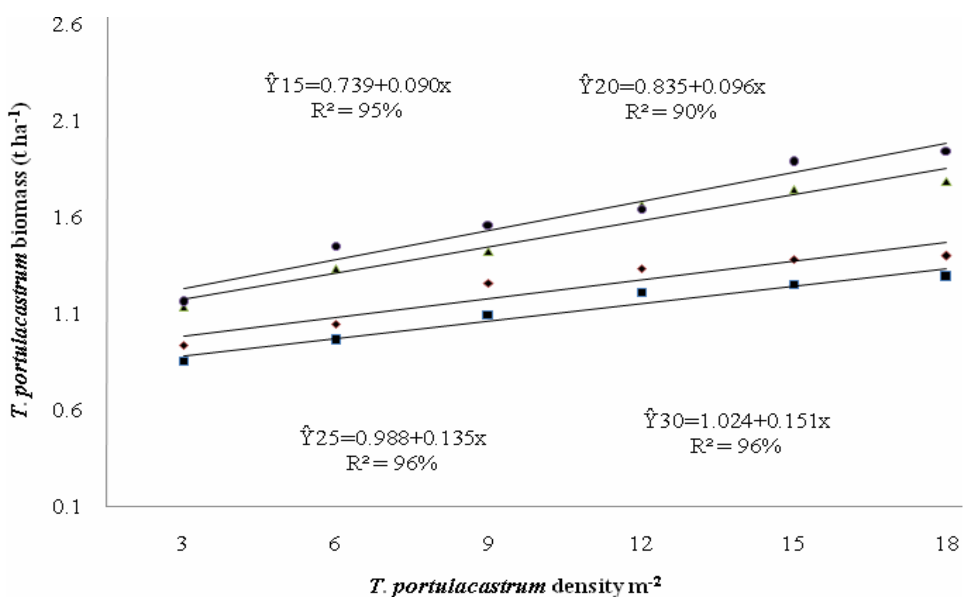

Fig. 4.11b. Interactive effects of maize plant spacing and *T. portulacastrum* density on *T. portulacastrum* biomass (t ha^{-1}) in 2007 (■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

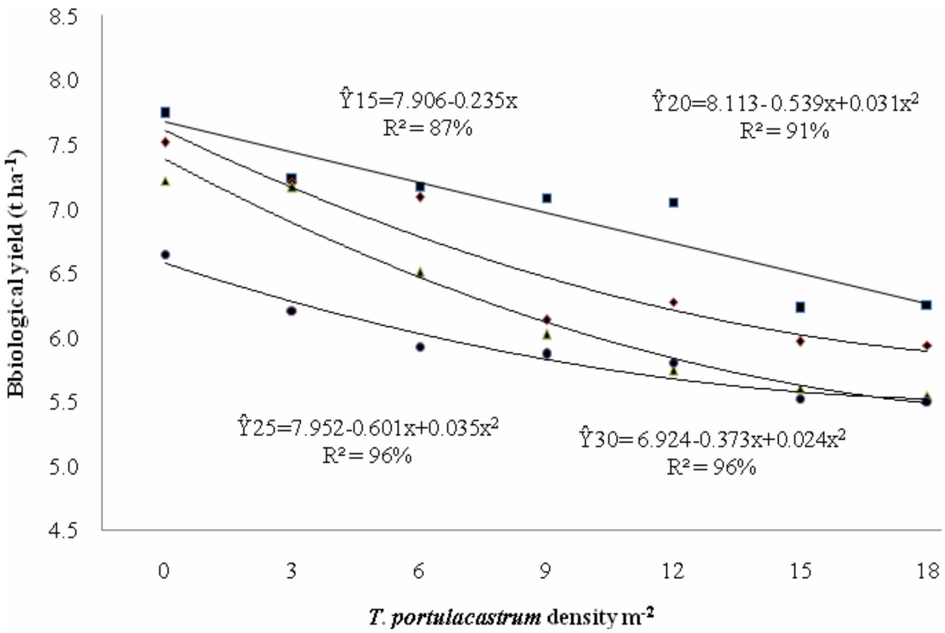

Fig. 4.12a. Interactive effects of maize plant spacing and *T. portulacastrum* density on maize biological yield (t ha^{-1}) in 2006 (■ = 15, ♦ = 20, ▲= 25,● = 30 cm)

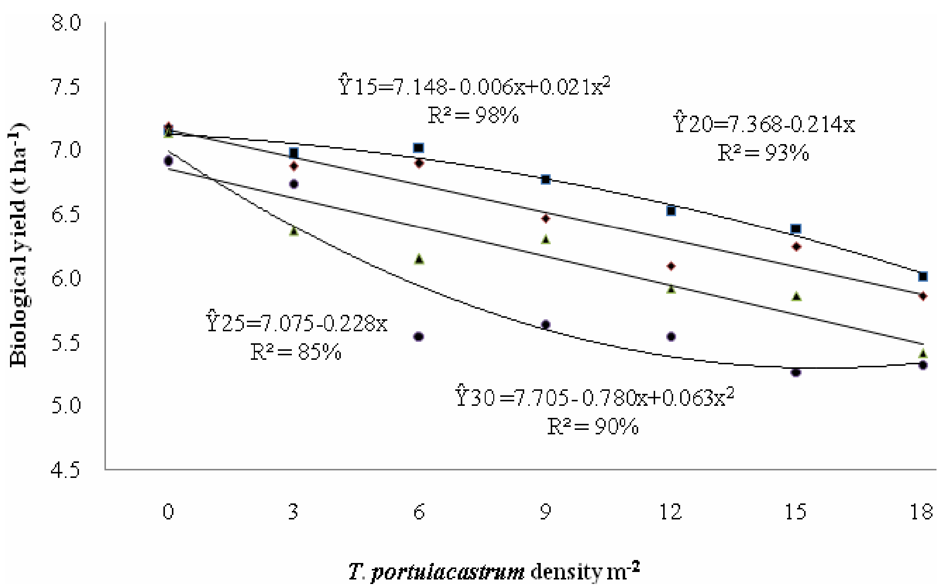

Fig. 4.12b. Interactive effects of maize plant spacing and *T. portulacastrum* density on maize biological yield (t ha^{-1}) in 2007 (■ = 15, ♦ = 20, ▲= 25,● = 30 cm)

4.13. Grain yield (t ha^{-1})

The effect of plant spacing on maize grain yield was significant in the two experiments conducted in the growing seasons of 2006 and 2007 (Appendix-B13). As shown in Table 4.7 higher grain yield of 2.85 t ha^{-1} was recorded in 15 cm plant spacing during 2006 that was at par with 20 cm spacing compared with lower grain yield of 2.30 t ha^{-1} in 30 cm plant spacing, again statistically similar to 25 cm plant spacing. Similarly during 2007, higher grain yield of 2.66 t ha^{-1} was noticed in narrow spacing (15 cm) which was statistically similar to 20 cm spacing compared with lower grain yield of 2.08 t ha^{-1} in wider spacing (30 cm). Despite the fact that yield components; like; ear weight, kernel weight and number of kernels ear^{-1} were lower in individual plants under narrow spacing yet the total grain yield was higher, due to more number of plants per unit area. Since all the plants had similar number of ears plant^{-1} thus decreasing plant spacing increased plant density and ultimately increased the number of ears per unit area, which increased grain yield. Another reason for high yield in narrow spacing was enhancement in competitiveness of maize to suppress *T. portulacastrum*, hence most of the resources were utilized by crop. Our results are closely related to the work of Bruns and Abbas (2003) who stated that maize grain yield increased with increasing plant density with no yield plateau or decline observed at the higher population. According to Randhawa (1995) minimizing space within maize plants minimized the individual plants leaf area index, total leaf area, ears weight, kernels ear^{-1} and kernel weight ear^{-1}, but maximized total grain yield. The lower plant population yielded higher ears plant^{-1}, ear length, kernels ear^{-1} and kernel weight ear^{-1}, but the higher plant population produced higher grain yield than lower plant population (Tyagi *et al*., 1998). Wider spacing improved all the developmental and yield characteristics but could not compensate the maize yield obtained from narrow spacing (Thakur *et al*., 1997). Optimum plant spacing is essential for enhancing the competitive ability of maize crop against weeds and minimizing yield losses. Our research showed that 15 cm plant spacing is the optimum spacing for maize crop interfered with *T. portulacastrum*.

The effect of *T. portulacastrum* density on the grain yield of maize was also significant in both years (Appendix-B13). As presented in Table 4.7, higher grain yield of 3.04 and 2.87 t ha^{-1} was recorded in check plots compared with lower grain yield of 2.14 and 2.0 t ha^{-1} in plots having higher weed density of 18 plants m^{-2} in 2006 and 2007, respectively.

In the growing season of 2006, the weed densities of 9, 12 and 15, 18 and during 2007 the weed densities of 12 and 15 m^{-2} were at par with each other. The decrease in yield with increasing density of *T. portulacastrum* was likely due to interspecific competition for resources. According to Jason *et al*. (2004), the presence of weeds reduced the maize grain yield, while Baye and Bouhache (2007) reported that longer the duration of competition between maize and weed, greater would be the reduction in yield. It has also been reported that grain yield was affected by giant ragweed interference (Williams and Masiunas, 2006) and maize grain yield was decreased in presence of *Eriochloa villosa* (Mickelson and Harvey, 1999).

Plant spacing x *T. portulacastrum* density interaction for grain yield was also significant in both the years (Appendix-B13). The trend lines showed that grain yield decreased linearly in all plant spacing with increasing weed densities (Fig. 4.13a & b). According to Liebman and Gallandt (1997), altering plant spacing describes 93-99% of the changes in grain yield, suppresses the weeds easily and plays a key role in increasing grain yield. Moreover, when plant spacing was decreased enough, the percent of plants decaying after emergence increased up to 27% during the vegetative period. Therefore, suitable plant spacing for each maize cultivar is one of the key factors for increasing grain yield.

4.14. Harvest index

As reported in Appendix-B14, effect of plant spacing on harvest index was not significant in the growing seasons of 2006 and significant in 2007. Higher harvest index (40.98 %) was noticed in 15 cm plant spacing and lower (38.83%) was observed in 30 cm plant spacing in 2006, though the difference was not significant. Similarly in 2007 the maximum harvest index (39.70%) was recorded in 15 cm plant spacing which was statistically similar to 20 cm plant spacing and lower harvest index (35.58 %) was recorded in 30 cm plant spacing that was at par with 25 cm plant spacing (Table 4.7). The experimental results indicated that harvest indices increased with decrease in maize plant spacing, thus at lower plant spacing intraspecific competition affected vegetative growth more than grain yield. Our results are in close agreement with the work of Waqar (2002) who reported that harvest index increased with decrease in plant spacing of maize. Similarly Olesky *et al*. (2001) were of the view that number of productive tillers $plant^{-1}$ decreased with increasing plant population above certain threshold level, which resulted in lower harvest index. Lemcoff (1994) reported that plant population density of 36600 and 73200 plants ha^{-1} resulted in similar harvest indices in maize crop. According to Sarlangue *et al.* (2007) increments in grain yield with increasing plant density are more associated with increases in biomass production than with increments in harvest index.

The density of *T. portulacastrum* had significant effect and weed density x plant spacing interaction was not significant in both years (Appendix-B14). Among the weed densities higher harvest indices of 41.89 and 40.56 % were recorded in check plots and lower harvest indices of 36.97 and 35.49 % were noticed in plots having the higher weed density of 18 m^{-2} in 2006 and 2007, respectively. In the growing season of 2006, the weed densities of 3, 6 and 9 m^{-2} and in 2007 weed densities of 3 and 6 m^{-2} were at par to each other (Table 4.7). According to Tessema and Tanner (1997) harvest index depends upon the weed species and density, moreover weed competition reduced harvest index (Pageau and Trembla, 1996) and maximum decline in harvest index was due to weed interference (Tollenaar *et al*., 1994).

The regression analysis showed that harvest index decreased quadratically with increase in weed density in all plant spacing, except 30 cm plant spacing which showed linear trend in 2006 (Fig. 4.14a & b). The decreasing trend in harvest index showed that *T. portulacastrum* affected grain yield more as compared to vegetative biomass. Similar results are reported by Tollenaar *et al*. (1994) that decline in harvest index was due to weed interference.

Table 4.7. Effects of maize plant spacing and *T. portulacastrum* density on grain yield (t ha^{-1}) and harvest index (%).

	Grain yield (t ha^{-1}) YEAR			Harvest index (%) YEAR	
PLANT SPACING (S) (cm)	2006	2007		2006	2007
15	2.85 a	2.66 a		40.98	39.70 a
20	2.68 a	2.53 a		40.66	38.76 ab
25	2.42 b	2.25 b		38.61	36.58 bc
30	2.30 b	2.08 c		38.83	35.58 c
LSD $_{(0.05)}$	0.17	0.15		NS	2.29
T. portulacastrum DENSITY (D) (m^{-2})					
0	3.04 a	2.87 a		41.89 a	40.56 a
3	2.92 b	2.60 b		41.98 a	38.65 ab
6	2.71 c	2.47 c		40.77 ab	38.61 abc
9	2.48 d	2.35 d		39.56 abc	37.32 bcd
12	2.43 d	2.21 e		39.08 bc	36.66 cd
15	2.21 e	2.16 e		38.15 bc	36.31 d
18	2.14 e	2.00 f		36.97 c	35.49 d
LSD $_{(0.05)}$	0.11	0.08		2.68	1.97
**INTERACTION (S x D)	*	*		NS	NS

Means followed by same lowercase letters in a column for each parameter and for each year are not significantly different at $p \leq 0.05$ (LSD tests).

S = Maize Plant Spacing (cm)
D = *T. portulacastrum* Density (m^{-2})
NS = Non Significant

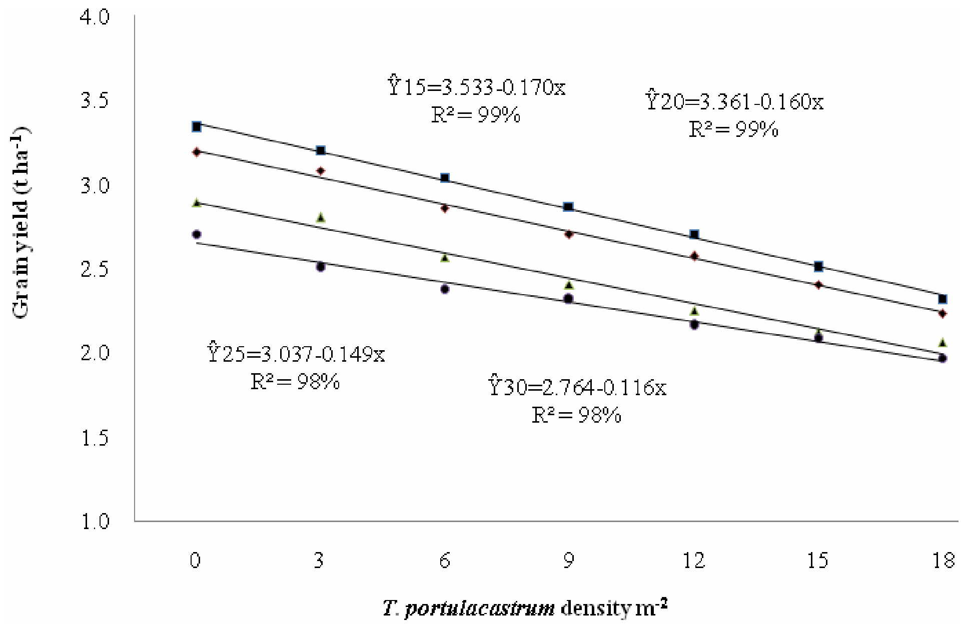

Fig. 4.13a. Interactive effects of maize plant spacing and *T. portulacastrum* density on grain yield (t ha^{-1}) in 2006 **(**■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

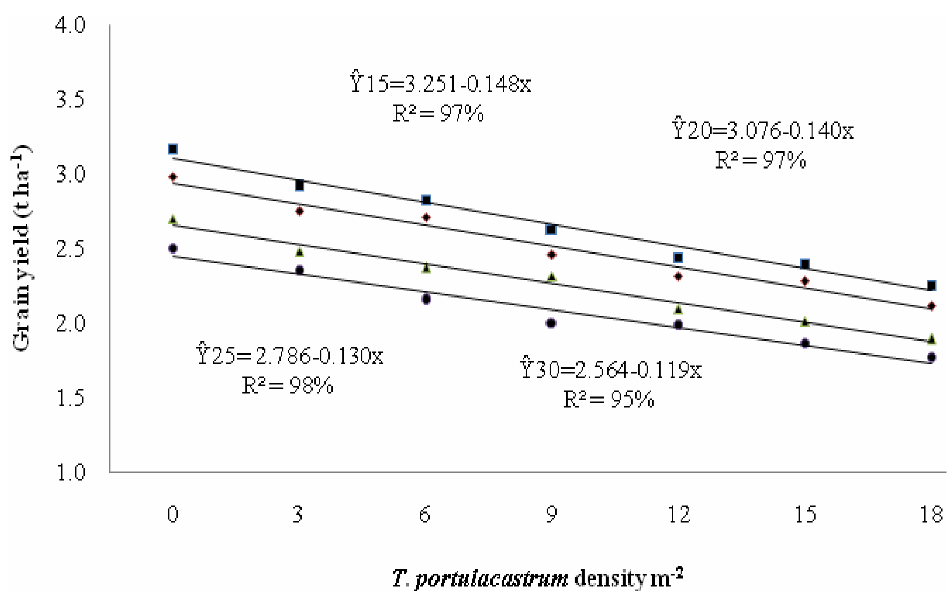

Fig. 4.13b. Interactive effects of maize plant spacing and *T. portulacastrum* density on grain yield (t ha^{-1}) in 2007 **(**■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

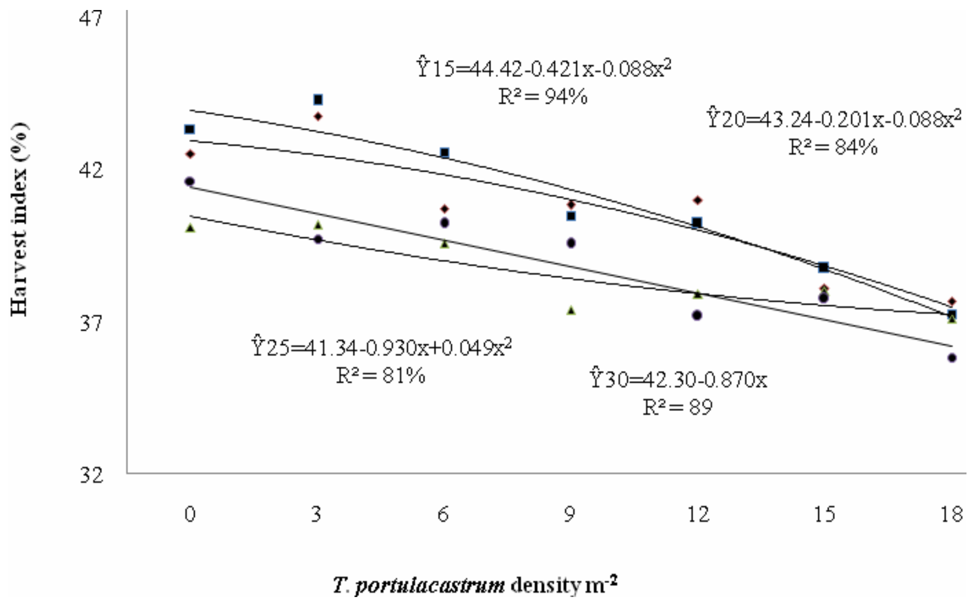

Fig. 4.14a. Interactive effects of maize plant spacing and *T. portulacastrum* density on harvest index (%) in 2006 **(**■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

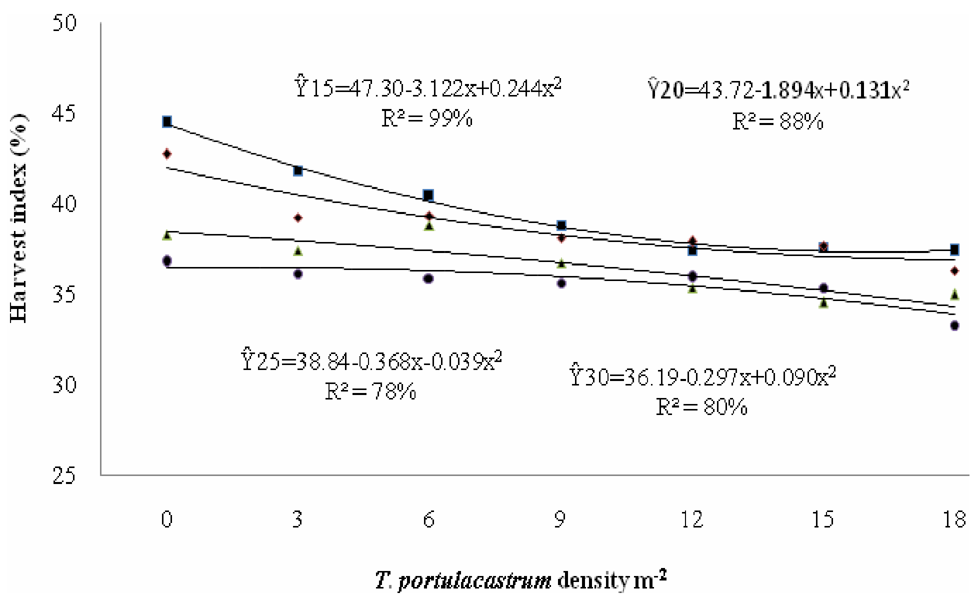

Fig. 4.14b. Interactive effects of maize plant spacing and *T. portulacastrum* density on harvest index (%) in 2007 **(**■ = 15, ♦ = 20, ▲= 25, ● = 30 cm)

4.15. Yield losses caused by *Trianthema portulacastrum* infestations

During both years lower yield losses due to weed competition were 16.8 and 18.7 % in 15 cm plant spacing as compared to maximum yield losses of 19.5 and 20.9 % in 30 cm plant spacing during 2006 and 2007, respectively. The results depicted that the competitiveness of maize plants spaced 15 cm apart were enhanced, as a result weeds were suppressed thereby reducing yield losses (Table 4.8 and 4.9). No doubt that at wider spacing more space was available to both crop and weed; however, *T. portulacastrum* proved to be more competitive because at wider spacing the growth (Table 4.6) and height (Table 4.2) of maize was retarded, thus space and other resources were utilized by weeds. According to Acciaresi and Zuluaga (2006) maize yield losses were lower in narrow spacing compared to wide spacing due to maize capability to suppress weeds.

In the case of *T. portulacastrum* density, maximum yield losses of 29.5 and 30.2 % were found in plots of higher weed density of 18 m^{-2} and lower losses of 4.2 and 9.3 % were recorded in plots having lower weed density of 3 m^{-2} (Table 4.8 & 4.9). The weed density of 6, 9, 12 and 15 plants m^{-2} caused a yield loss of 11.1, 18.6, 20.4 and 27.2 % and 14.3, 18.3, 23.2, and 25.1% against check plots in 2006 and 2007, respectively. In similar studies maize and weed interference can reduce maize yields up to 19% (Johnson *et al*., 2007). Whereas season long weed interference resulted in 83.03% corn yield reduction (Usman *et al*., 2001) and high weed pressure declined grain yield by 65% in maize (Chikoye *et al*., 2008).

Table 4.8. Percentage of grain yield losses at varying *T. portulacastrum* density and maize plant spacing during the 2006 season.

Weed Density	Plant Spacing				Means
	15	20	25	30	
3	4.0	1.7	0.3	10.96	**4.2**
6	8.8	10.3	11.2	14.04	**11.1**
9	14.1	21.6	22.2	16.43	**18.6**
12	15.2	19.3	25.1	22.02	**20.4**
15	28.5	28.7	26.7	24.71	**27.2**
18	30.4	29.9	28.8	28.92	**29.5**
Means	**16.8**	**18.6**	**19.1**	**19.5**	

Table 4.9. Grain yield losses (%) of maize crop at varying *T. portulacastrum* density and plant spacing during the 2007 season.

Weed Density	Plant Spacing				Means
	15	20	25	30	
3	8.0	12.1	12.9	4.08	**9.3**
6	10.9	11.6	13.2	21.65	**14.3**
9	17.1	19.8	15.4	21.11	**18.3**
12	22.9	24.7	23.4	21.68	**23.2**
15	24.3	23.2	26.3	26.57	**25.1**
18	29.0	31.0	30.8	30.16	**30.2**
Means	**18.7**	**20.4**	**20.3**	**20.9**	

V. SUMMARY

Horse purslane (*Trianthema portulacastrum* L.) is one of the most competitive weeds of summer maize and vegetables throughout Pakistan and its competitiveness like other weeds, depends upon its density and other associated factors which may vary from field to field. Therefore, the competition studies between maize and weed were undertaken during the summer of 2006 and 2007 at Agricultural Research Farm, NWFP Agricultural University Peshawar, Pakistan. The experiments were laid out in Randomized Complete Block (RCB) design with split plot arrangements, having three replications. Four plant spacings viz., 15, 20, 25 and 30 cm were kept in main plots while seven weed densities of 0, 3, 6, 9, 12, 15 and 18 Plants m^{-2} were assigned to the sub plots. The years effect was significant due to variation in pattern of rainfall and temperature. The grain yield was affected by years, plant spacing and weed density. Decreasing plant spacing increased the grain yield. The narrow plant spacing produced higher grain yields of 2.85 and 2.66 t ha^{-1} as compared to 2.30 and 2.08 t ha^{-1} in wider spacing during 2006 and 2007, respectively. Similarly, with increasing weed density, the grain yield was decreased. Higher grain yield of 3.04 t ha^{-1} in 2006 and 2.87 t ha^{-1}in 2007 was recorded in control plots. Each increment in weed density lowered the grain yield in a linear fashion. Decreasing the distance between plants increased total yield but negatively affected the yield components, like ear weight and number of kernels ear^{-1} of the individual maize plant. The biological yield of maize was also affected by years, plant spacing and weed density. Plant spacing of 15 cm for crops grown in 2006 and 2007 also resulted in respective higher biological yields of 6.96 and 6.69 t ha^{-1} in comparison with crop plants at 30 cm spacing, with biological yields of 5.92 and 5.85t ha^{-1}. An increasing trend in biological yield was noticed with decrease in plant spacing, hence at lower spacing the number of plants per unit area increased, which increased biological yield. Similarly, control plots showed higher biological yields of 7.28 and 7.09 t ha^{-1} as compared to 5.81and 5.65 t ha^{-1} in higher weed density of 18 m^{-2} plots during 2006 and 2007, respectively. Plant spacing of 15 cm resulted in lower fresh weed biomass of 0.91and 0.88 t ha^{-1} and plant spacing of 30 cm showed higher biomass of 1.33 and 1.21t ha^{-1}

during 2006 and 2007, respectively. Similarly, the lower weed density of 3 plants m^{-2} resulted in lower weed biomass of 0.97 and 0.93 t ha^{-1}as compared to 1.55 and 1.49 t ha^{-1} in higher weed density of 18 m^{-2} during 2006 and 2007, respectively. The decreasing plant spacing and increasing weed density delayed tasseling, silking and maturity of maize. The number of ears $plant^{-1}$ and rows ear^{-1} were not significantly affected by years, plant spacing and weed density. The higher kernels ear^{-1} of 319 and 309 were recorded in 30 cm plant spacing as compared to lower kernels ear^{-1} of 292 and 268 in 15 cm plant spacing in 2006 and 2007, respectively. The lower weed density of 3 plants m^{-2} did not reduce the number of kernels ear^{-1}. The higher number of kernels ear^{-1} (323 & 308) was recorded in check plots and lower kernels ear^{-1} (282 & 269) was noticed in plots having higher weed density of 18 plants m^{-2} in 2006 and 2007, respectively. The higher leaf area index of 2.99 and 2.93 was recorded in narrow plant spacing of 15 cm as compared to 1.41 and 1.35 in 30 cm plant spacing. Similarly, higher leaf area index of 2.99 and 2.74 was recorded in control plots as compared to 1.79 and 1.73 in plots having higher weed density of 18 plants m^{-2}. The leaf area index of maize decreased with each increment in weed density due to increase in weed density and competition. Lowest yield losses of 16.8 and 18.7 % were recorded in 15 cm plant spacing and highest yield losses of 19.5 and 20.9 % were recorded in plants spaced 30 cm apart during 2006 and 2007, respectively. The competitiveness of maize plants spaced 15 cm apart suppressed growth of *T. portulacastrum*, thereby reducing yield losses. Losses due to weeds were 4.2, 11.1, 18.6, 20.4, 27.2 and 29.5 % during 2006 and 9.3, 14.3, 18.3, 23.2, 25.1 and 30.2 % during 2007 with the infestation of 3, 6, 9, 12, 15 and 18 weeds m^{-2}. The study showed that *T. portulacastrum* is an aggressive weed and yield losses increased with each increment in its density. All the ear traits improved with increasing plant spacing but could not compensate the total grain and biological yield obtained from narrow spacing. Though the losses were reduced in narrow spacing yet it required other control measures along with the narrow plant spacing to keep *T. portulacastrum* below the threshold level.

VI. CONCLUSIONS AND RECOMMENDATIONS

The human population is increasing while agricultural land is shrinking with time; therefore, a vertical increase in the productivity per unit area is necessary to sustain the existing population and its ensuing increase. In crop husbandry, the importance of weeds cannot be ignored. Knowledge-based correct weed management decision on relationship between the weed densities and the crop yield losses is of paramount importance. To minimize weed losses due to weeds, knowledge on the optimum plant spacing is of immense importance to plan any integrated weed management program.

CONCLUSIONS:

1. All densities of *Trianthema portulacastrum* were effective in reducing yield.
2. Yield losses of 4.2, 11.1, 18.6, 20.4, 27.2 and 29.5 % in the growing season of 2006 and 9.3, 14.3, 18.3, 23.2, 25.1 and 30.2 % in the growing season of 2007 were found with densities of 3, 6, 9, 12, 15 and 18 plants of *T. portulacastrum* m^{-2}.
3. Plant spacing of 15 cm was much suitable, competing with *T. portulacastrum* more effectively.
4. Higher grain yields (2.85t ha^{-1} and 2.66 t ha^{-1}) were obtained from 15 cm plant spacing followed by 20 cm plant spacing with parallel yield brackets of 2.68t ha^{-1} and 2.53 t ha^{-1} in the growing seasons of 2006 and 2007, respectively.

RECOMMENDATIONS:

1. Even a single plant of *T. portulacastrum* m^{-2} is detrimental to yield loss, therefore it should be treated as noxious weed.
2. In the prevailing situations, 15 cm plant spacing should be adopted by the maize growing farmers.
3. Manipulation of plant spacing alone was not enough to suppress *T. portulacastrum*, therefore other management practices should also be applied for achieving better yields.

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APPENDICES

Appendix-A: Combined ANOVA (Analysis of variance) for different parameters of maize as affected by plant spacing and *Trianthema portulacastrum* density.

Appendix-A1.Combined ANOVA showing Mean Square values for days to 50% tasseling and days to 50% silking.

Source of variation	DF	Days to 50% tasseling	Days to 50% silking
Year	1	13.714*	76.006*
Replication x Year	4	5.333	8.810*
Maize plant spacing	3	49.913*	24.054*
Year x Spacing	3	1.063	3.069
Error (a)	12	4.190	3.079
T. portulacastrum density	6	102.437*	41.242*
Year x Density	6	0.825	1.770
Spacing x Density	18	2.098	2.771*
Year x Spacing x Density	18	6.360*	1.944
Error (b)	96	2.219	1.234
Coefficient of variation (%)		2.80	1.83

Appendix-A2. Combined ANOVA showing Mean Square values for days to maturity and plant height (cm).

.Source of variation	DF	Days to maturity	Plant height (cm)
Year	1	10.500*	1278.984*
Replication x Year	4	5.054*	33.316
Maize plant spacing	3	14.944*	63.423
Year x Spacing	3	1.802	4.486
Error (a)	12	1.569	189.935
T. portulacastrum density	6	39.927*	1160.370*
Year x Density	6	0.264	24.164
Spacing x Density	18	1.718*	108.445*
Year x Spacing x Density	18	1.140	42.129
Error (b)	96	0.774	40.575
Coefficient of variation (%)		0.95	3.79

Appendix-A3. Combined ANOVA showing Mean Square values for number of ears plant^{-1} and ear weight (g).

Source of variation	DF	Number of ears plant^{-1}	Ear weight (g)
Year	1	0.004	1748.595*
Replication x Year	4	0.010	10.202
Maize plant spacing	3	0.004	123.778
Year x Spacing	3	0.000	2.183
Error (a)	12	0.017	68.266
T. portulacastrum density	6	0.008	793.429*
Year x Density	6	0.000	32.401*
Spacing x Density	18	0.000	35.926*
Year x Spacing x Density	18	0.000	20.729
Error (b)	96	0.026	13.465
Coefficient of variation (%)		15.84	3.84

Appendix-A4. Combined ANOVA showing Mean Square values for 1000-kernel weight (g) and number of rows ear^{-1}.

Source of variation	DF	1000-kernel weight (g)	Number of rows ear^{-1}
Year	1	2547.408*	0.242
Replication x Year	4	43.299	0.127
Maize plant spacing	3	572.683*	0.126
Year x Spacing	3	42.126	0.012
Error (a)	12	18.765	0.763
T. portulacastrum density	6	1045.569*	0.600
Year x Density	6	12.815	0.010
Spacing x Density	18	1.713	0.005
Year x Spacing x Density	18	6.567	0.008
Error (b)	96	91.923	1.428
Coefficient of variation (%)		5.11	9.04

Appendix-A5. Combined ANOVA showing Mean Square values for number of kernels ear^{-1} and leaf area index.

Source of variation	DF	Number of kernels ear^{-1}	Leaf area index
Year	1	9404.829*	1.199*
Replication x Year	4	339.127	0.183
Maize plant spacing	3	9535.592*	20.619*
Year x Spacing	3	373.480	0.084*
Error (a)	12	298.431	0.020
T. portulacastrum density	6	5426.974*	4.793*
Year x Density	6	26.713	0.041*
Spacing x Density	18	395.015*	0.132*
Year x Spacing x Density	18	129.650	0.023 NS
Error (b)	96	142.028	0.011
Coefficient of variation (%)		4.02	5.48

Appendix-A6. Combined ANOVA showing Mean Square values for *T. portulacastrum* biological yield (t ha^{-1}) and biological yield (t ha^{-1}).

Source of variation	DF	*T. portulacastrum* biomass yield (t ha^{-1})	Biological yield (t ha^{-1})
Year	1	0.155	0.731*
Replication x Year	4	0.028	0.135
Maize plant spacing	3	0.010	7.013*
Year x Spacing	3	0.001	0.100
Error (a)	12	0.053	0.147
T. portulacastrum density	6	0.131*	6.540*
Year x Density	6	0.002	0.117
Spacing x Density	18	0.009	0.165
Year x Spacing x Density	18	0.009	0.162
Error (b)	96	0.040	0.136
Coefficient of variation (%)		19.13	5.79

Appendix-A7. Combined ANOVA showing Mean Square values for grain yield (t ha^{-1}) and harvest index.

Source of variation	DF	Grain yield (t ha^{-1})	Harvest index (%)
Year	1	1.371*	187.364*
Replication x Year	4	0.039	18.174
Maize plant spacing	3	2.734*	100.315*
Year x Spacing	3	0.013	7.166
Error (a)	12	0.043	19.784
T. portulacastrum density	6	2.400*	75.921*
Year x Density	6	0.041*	2.677
Spacing x Density	18	0.021	3.162
Year x Spacing x Density	18	0.030*	2.801
Error (b)	96	0.014	8.202
Coefficient of variation (%)		4.70	7.40

Appendix-B: ANOVA (analysis of variance) of growing seasons of 2006 and 2007 for different parameters of maize as influenced by crop spacing and *T. portulacastrum* density.

Appendix-B1. ANOVA for the growing seasons of 2006 and 2007 showing Mean Squares values for days to 50% tasseling in 2006 and 2007.

Source of variation	DF	Days to 50% tasseling 2006	Days to 50% tasseling 2007
Replication	2	1.226	9.440
Maize plant spacing	3	31.631*	19.345*
Error (a)	6	5.131	3.250
T. portulacastrum density	6	50.040*	53.222*
Spacing x Density	18	3.251*	5.206*
Error (b)	48	1.669	2.770
Coefficient of variation (%)		2.42	3.15

Appendix-B2. ANOVA for the growing seasons of 2006 and 2007 showing Mean Squares values for days to 50% silking in 2006 and 2007.

Source of variation	DF	Days to 50% silking 2006	Days to 50% silking 2007
Replication	2	12.893	4.726
Maize plant spacing	3	21.651*	5.472
Error (a)	6	4.258	1.901
T. portulacastrum density	6	23.623*	19.389*
Spacing x Density	18	2.660*	2.056*
Error (b)	48	1.347	1.121
Coefficient of variation (%)		1.89	1.76

Appendix-B3. ANOVA for the growing seasons of 2006 and 2007 showing Mean Squares values for days to maturity in 2006 and 2007.

Source of variation	DF	Days o maturity 2006	Days to maturity 2007
Replication	2	1.393	8.714
Maize plant spacing	3	11.83*	4.921*
Error (a)	6	2.218	0.921
T. portulacastrum density	6	21.57*	18.623*
Spacing x Density	18	1.298*	1.560*
Error (b)	48	0.692	0.855
Coefficient of variation (%)		0.90	1.00

Appendix-B4. ANOVA for the growing seasons of 2006 and 2007 showing Mean Squares values for plant height (cm) in 2006 and 2007.

Source of variation	DF	Plant height (cm) 2006	Plant height (cm) 2007
Replication	2	24.333	42.299
Maize plant spacing	3	29.222	38.687
Error (a)	6	115.413	264.457
T. portulacastrum density	6	525.913*	658.621*
Spacing x Density	18	40.611*	109.963*
Error (b)	48	21.573	59.576
Coefficient of variation (%)		2.72	4.67

Appendix-B5. ANOVA for the growing seasons of 2006 and 2007 showing Mean Squares values for number of ears plant^{-1} in 2006 and 2007.

Source of variation	DF	Number of ears plant^{-1} 2006	Number of ears plant^{-1} 2007
Replication	2	0.018	0.001
Maize plant spacing	3	0.003	0.001
Error (a)	6	0.024	0.011
T. portulacastrum density	6	0.005	0.004
Spacing x Density	18	0.000	0.000
Error (b)	48	0.026	0.026
Coefficient of variation (%)		15.80	15.88

Appendix-B6. ANOVA for the growing seasons of 2006 and 2007 showing Mean Squares values for ear weight (g) in 2006 and 2007.

Source of variation	DF	Ear weight (g) 2006	Ear weight (g) 2007
Replication	2	2.583	17.821
Maize plant spacing	3	77.282*	48.679
Error (a)	6	15.853	120.679
T. portulacastrum density	6	263.913*	561.917*
Spacing x Density	18	16.569*	40.086*
Error (b)	48	5.244	21.687
Coefficient of variation (%)		2.32	5.05

Appendix-B7. ANOVA for the growing seasons of 2006 and 2007 showing Mean Squares values for 1000-kernel weight (g) in 2006 and 2007.

Source of variation	DF	1000-kernel weight (g) 2006	1000-kernel weight (g) 2007
Replication	2	59.407	27.191
Maize plant spacing	3	153.79*	461.020*
Error (a)	6	7.4409	30.089
T. portulacastrum density	6	430.16*	628.225*
Spacing x Density	18	3.1982	5.082
Error (b)	48	98.905	84.941
Coefficient of variation (%)		5.19	5.02

Appendix-B8. ANOVA for the growing seasons of 2006 and 2007 showing Mean Squares values for number of rows ear^{-1} in 2006 and 2007.

Source of variation	DF	Number of rows ear^{-1} 2006	Number of rows ear^{-1} 2007
Replication	2	0.195	0.058
Maize plant spacing	3	0.035	0.103
Error (a)	6	1.031	0.494
T. portulacastrum density	6	0.250	0.360
Spacing x Density	18	0.005	0.007
Error (b)	48	1.839	1.017
Coefficient of variation (%)		10.23	7.65

Appendix-B9. ANOVA for the growing seasons of 2006 and 2007 showing Mean Squares values for number of kernels ear^{-1} in 2006 and 2007.

Source of variation	DF	Number of kernels ear^{-1} 2006	Number of kernels ear^{-1} 2007
Replication	2	557.058	121.197
Maize plant spacing	3	3726.517*	6182.555*
Error (a)	6	208.009	388.853
T. portulacastrum density	6	2682.879*	2770.808*
Spacing x Density	18	273.463*	251.202*
Error (b)	48	148.608	135.447
Coefficient of variation (%)		4.01	4.03

Appendix-B10. ANOVA for the growing seasons of 2006 and 2007 showing Mean Squares values for leaf area index in 2006 and 2007.

Source of variation	DF	Leaf area index	Leaf area index
Replication	2	0.321	0.100
Maize plant spacing	3	2.652*	1.632*
Error (a)	6	0.041	0.007
T. portulacastrum density	6	10.753*	8.091*
Spacing x Density	18	0.172*	0.090*
Error (b)	48	0.020	0.023
Coefficient of variation (%)		6.69	7.39

Appendix-B11. ANOVA for the growing seasons of 2006 and 2007 showing Mean Squares values for *T. portulacastrum* biomass (t ha^{-1}) in 2006 and 2007.

Source of variation	DF	*T. portulacastrum* biomass (t ha^{-1}) 2006	*T. portulacastrum* biomass (t ha^{-1}) 2007
Replication	2	0.027	0.010
Maize plant spacing	3	0.847*	0.446*
Error (a)	6	0.099	0.006
T. portulacastrum density	6	3.454*	2.993*
Spacing x Density	18	0.035*	0.021*
Error (b)	48	0.019	0.009
Coefficient of variation (%)		12.29	8.92

Appendix-B12. ANOVA for the growing seasons of 2006 and 2007 showing Mean Squares values for biological yield (t ha^{-1})in 2006 and 2007.

Source of variation	DF	Biological yield (t ha^{-1}) 2006	Biological yield (t ha^{-1}) 2007
Replication	2	0.016	0.253
Maize plant spacing	3	4.173*	2.940*
Error (a)	6	0.139	0.156
T. portulacastrum density	6	3.740*	2.917*
Spacing x Density	18	0.157	0.170
Error (b)	48	0.158	0.113
Coefficient of variation (%)		6.18	5.34

Appendix-B13. ANOVA for the growing seasons of 2006 and 2007 showing Mean Squares values for grain yield (t ha^{-1}) in 2006 and 2007.

Source of variation	DF	Grain yield (t ha^{-1}) 2006	Grain yield (t ha^{-1}) 2007
Replication	2	0.063	0.015
Maize plant spacing	3	1.315*	1.432*
Error (a)	6	0.048	0.038
T. portulacastrum density	6	1.395*	1.047*
Spacing x Density	18	0.032*	0.019*
Error (b)	48	0.017	0.010
Coefficient of variation (%)		5.14	4.13

Appendix-B14. ANOVA for the growing seasons of 2006 and 2007 showing Mean Squares values for harvest index (%) in 2006 and 2007.

Source of variation	DF	Harvest index (%) 2006	Harvest index (%) 2007
Replication	2	20.972	15.376
Maize plant spacing	3	31.335	76.147*
Error (a)	6	30.381	9.186
T. portulacastrum density	6	42.724*	35.875*
Spacing x Density	18	2.598	3.365
Error (b)	48	10.649	5.756
Coefficient of variation (%)		8.21	6.37