GROWTH AND YIELD RESPONSE OF AUTUMN PLANTED HYBRID MAIZE TO HORSE PURSLANE *(Trianthema portulacastrum)* INTERFERENCE

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ABSTRACT

The assumed comparative losses of horse purslane's (vern. It sit) losses relative to other weeds are higher. The study was conducted during summer season 2018 at Research Farm Muhammad Nawa Sharif University of Agriculture, Multan, Pakistan on a field having high infestation history of horse purslane. Study was carried out in a RCBD with three replications. Experiment consisted of ten treatments viz: weeds free (whole season), horse purslane free till 20 Days after emergence (DAE), horse purslane free till 40 DAE, horse purslane free till 60 DAE, all weeds free 20 DAE, all weeds free 40 DAE, all weeds free 60 DAE, weedy check (all weeds), weedy check except horse purslane and weedy check containing only horse purslane. The data showed the maximum yield and yield related parameters like plant height (178.49 cm), cob weight (27.88 g), cob length (28.72 cm), stover yield (10.20 t ha^{-1}), kernel yield (6.86 t ha^{-1}) and growth parameters like crop growth rate, leaf area index, leaf area duration and net assimilation rate in weeds free (whole season). In treatment (horse purslane free 40 DAE) kernel yield was higher as compared to treatments such as horse purslane free 20 DAE and 40 DAE. As the interference duration increased over 45 days after emergence, significant reduction in yield and growth of maize was observed. It can be concluded that farmers should control horse purslane within first 45 days in maize field.

Keywords: *Trianthema portulacastrum*, weed competition, weed dynamics, yield, *Zea mays*

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INTRODUCTION

In Pakistan, during FY 2017-18, area under maize cultivation was 1,229 thousand ha and the total production was 5.702 million tons, whereas yield was 4,640 kg ha^{-1} (GOP, 2018). During the same year worldwide area under maize was 1,80,639 thousand ha with a production of 10,33,664 thousand metric tons and mean yield of 5.72 metric tons (FAOSTAT, 2020). Maize contribution in GDP in Pakistan is 0.5 percent and value addition in agriculture is 2.4 percent. Maize production and area has decreased due to increase in area under other crops like cotton, sugarcane and rice (GOP, 2018). In leather industry, maize provides tanning material. Maize is the principal fodder for the livestock during summer months (Arain, 2013). Pakistan's maize yield per hectare is very low despite favorable environmental conditions and high yielding varieties. Maize is grown under various climatic conditions. Due to best adaptability of environment its most cultivation is in autumn season (Ashiq and Ata, 2005). Weeds also grow well during this season and impose loss on this crop and reduce its yield significantly.

Among various factors reducing crop yield, weed infestation is the major factor in reducing the maize yield. Weeds are one of the main problems in a cropped areas which reduce the maize yield by 25 - 50%. In rainy areas, weeds in maize fields are controlled by inter-culture, which is expensive and time consuming method (Riaz *et al*., 2007). Maize yield is significantly reduced due to season long competition by weeds (Dalley *et al*., 2006). Uncontrolled weed growth is responsible for 35-70 % decrease in maize kernel yield (Ford and Pleasant, 1994). Usman *et al*. (2001) reported that unmanaged weed growth reduces maize average kernel yield by 83%.

In maize crop, total 69 weed species are reported and horse purslane (vern it-sit) was realized as the most serious weed (Kumar and Singh, 1983). *Trianthema portulacastrum* L. is the most common and serious weed invading maize crop. Maize is more sensitive to horse purslane as it reduces maize yield by 32 % (Balyan and Bhan, 1989). Horse purslane is toxic weed and incurs competition for nutrients in maize crop (Gupta and Mukerji, 2001).

In Pakistan, horse purslane (vern. *it sit*) is one of the serious summer weeds (Randhawa *et al.*, 2002). *Trianthema portulacastrum* L. has small white flowers, produced in huge amount during the period from April to October and productivity is high. Flowering initiates 20 to 30 days after emergence, mature plant is capable to produce 3,330 fruits per plant and 6-10 seeds per fruit (Galinato *et al.,* 1999). Horse purslane is more aggressive than the other associated weeds in maize fields. However, due to relatively higher aggressiveness of horse purslane over other weeds, the current study was designed to assess the relative damage of horse purslane to other weeds on growth and yield of maize.

MATERIALS AND METHODS

Study having three replications was carried out in Randomized complete block design. The sowing of maize *(Zea mays* L.*)* was done on 31st July 2108. Cultural practices were kept uniform for all the plots. Maize hybrid 'Monsanto Dk-6714' was sown. Row to row distance and distance between the plants was maintained at 75 and 15 cm, respectively. Recommended dose of N: P: K (200:125:125 kg ha^{-1}) was applied. Seed rate of 25 kg ha^{-1} was used for sowing through dibbling on beds. Net plot size was kept at 3.0 m × 5.0 m. Canal and tube well water was used for irrigation. Weeds were controlled by hand weeding as per treatment

Ten treatments were used in the study were as under:

T_1 : Weed free (whole season)

T_2 : Horse purslane free till 20 Days After Emergence (DAE)

T_3 : Horse purslane free till 40 DAE

T_4 : Horse purslane free till 60 DAE

T_5 : All weeds free 20 DAE

T_6 : All weeds free 40 DAE

T_7 : All weeds free 60 DAE

T_8 : Weedy check (all weeds except horse purslane)

T_9 : Weedy check (only horse purslane)

T_{10}: Weedy check (all weeds)

Data regarding the weeds density and dry weight was recorded from an area of 1 m^{-2} at 15 days interval after emergence till harvest. Weeds within the quadrate were removed and individual density of weed was determined by counting the total number of particular weed in a quadrate. For dry weight, weeds were oven dried for 72 hours at 60º C. Dried weeds were taken out and weighed individually by using the electric weight balance. Plant height of 12 plants at maturity was measured by using the measuring tape. Cob length was measured by using the measuring tape. Cob weight from 12 plants in a plot was measured by using digital weighing balance. Stover yield was calculated by selecting 12 plants from each plot. For kernel yield, kernels from 12 plants were collected, weight was recorded and converted into t ha^{-1}. Crop growth rate, leaf area index, leaf area duration were recorded at 15 days interval after 45 days of emergence. Formula proposed by Hunt (1978) was used for calculating the crop growth rate.

$$CGR\ (g\,m^{-2}d^{-1}) = \frac{W_2 - W_1}{T_2 - T}$$

Formula given by Watson (1947) was used for calculating the LAI.

$$LAI = \frac{Leaf\ area}{Land\ area}$$

Beadle's (1987), formula was used for computing the

$$LAD = \frac{LA\ [(LAI_1 + LAI_2) \times (t_2 - t_1)]}{2}$$

Beadle's (1987) formula was used for computing the NAR

$$NAR = \frac{\text{Total Dry weight (at harvest)}}{\text{Leaf area duration (LAD)}}$$

RESULTS AND DISCUSSION

Plant height (cm)

Plant height was significantly affected by different treatments used in the study. Significantly maximum plant height (178.49 cm) was recorded in treatment (weeds free whole season) as there was no competition for resources and nutrients. Available nutrients and other resources were effectively utilized by the plants which resulted in increased plant height, whereas treatment (weedy check, all weeds) showed significantly lowest plant height (125.95 cm) as compared to all other treatments. Plant height (168.83 m) in treatment (all weeds free 40 DAE) was statistically similar to height of plants (168.19 cm) in treatment (horse purslane free 60 DAE) [Table-1]. It might be due to variation in type of weeds present in both treatments. In plots where horse purslane free 40 DAE was maintained, as all other weeds were allowed to grow except horse purslane for 40 DAE, horse purslane was also allowed to grow and compete for all the available nutrients and resources so all the weeds along horse purslane reduce the plant height (162.04 cm). Plant height of 153.90 cm in (horse purslane free 20 days after emergence) was statistically similar to 156.90 cm in treatment (all weeds free 20 DAE). In both treatments weeds were present for most of the growing period so there was no significant difference in plant height resulting in equal competition in both treatments. In (weedy check except horse purslane) plant height (140.07 cm) was reduced as maximum amount of nutrients and all other resources were shared between weeds and crop (Table-1). These results are similar to the findings of Azhar (2009), who stated that increase in maize plant height was due to the better suppression of weeds which resulted in reduced competition with maize for growth factors.

Cob weight (g)

The highest cob weight (339.33 g) recorded in treatment (weeds free whole season) was significantly highest as compared to all the other treatments whereas in treatment (weedy check all weeds) cob weight of 219.33 g was recorded which was significantly lowest (Table-1). Next maximum cob weight (302.67 g) was recorded in (all weeds free 60 DAE maintained plots) as essential nutrients and other resources were present in abundance. All weeds free 40 DAE, weed crop competition period was enhanced but still sufficient amount of moisture nutrients and other resources were present as the result of which cob weight of 297.33 g was recorded. In plots where horse purslane was not allowed to grow for 60 DAE however other weeds were allowed to grow which competed with maize plants had cob weight 286.00 g (horse purslane free 40 DAE), horse purslane among other weeds was able to compete with crop for longer period as the result of this interference nutrient and resources supply was lowered for crop use by weeds. Cob weight (250.00 g) was reduced in (all weeds free 20 DAE), as a result of high weed growth and development as weeds are effective utilizers of resources as compared to crop so the presence of weeds during the critical stages resulted in decreased cob weight. Horse purslane free till 20 DAE resulted in increased weed crop interference and all other weeds were present during the early growth of crop. Nutrients and resources were utilized by weeds resulting in low cob weight (240.00 g). In plots maintained as weedy check all weeds except horse purslane, uncontrolled growth and development of weeds from early growth of crop had negative effect on cob weight (226.67 g) as crop was deprived of all the essential nutrients and resources during the season due to interference with weeds for whole season. Statistically next lowest cob weight (222.67 g) was reported in (weedy check only horse purslane), due to aggressive and rapid growth nature of horse purslane, the resources were utilized by horse purslane and as a result of horse purslane dominance and interference cob weight was highly reduced. These results are in agreement with the outcomes of Williams and Masiunas (2006), who stated that maize ear weight was significantly decreased as a result of *Ambrosia trifida* L. interference.

Cob length (cm)

Cob length is an important yield component. It was significantly affected by all the treatments employed in the study. Statistically maximum cob length of (28.72 cm) was observed in the plots kept weed free whole season and lowest cob length (21.50 cm) was recorded in treatment (weedy check all weeds) [Table=1]. Statistically maximum cob length was obtained in the treatment (weeds free whole season) which may be due to the elimination of weed interference and long weed free period resulting in increase in growth of crop. Statistically next maximum cob length (28.12 cm) was reported in plots where all weeds were kept from growing for 60 DAE. Growth resources were favorable for the crop growth and development as weeds were controlled for maximum period. Plots where all weeds were controlled for first 40 DAE weeds existence for rest of the growing period was long enough to exert more weed interference on crop growth which was translated in reduced cob length of 26.46 cm. Further increase in horse purslane interference after 60 DAE would have resulted in reduced uptake of growth resources by maize when compared with horse purslane. Hence the impact was reflected in the form of shorter cobs 26.01 cm. In plots where horse purslane interfered with maize plants in field for even more duration i.e. horse purslane free 40 DAE further reduced the cob length (25.15 cm). It could be attributed to more duration available for interference of horse purslane with maize plants. In plots where all weeds were kept for growing for initial 20 days and after that were allowed to exert interference on growth and development of maize plants revealed significant reduction in cob length (24.15 cm). plots where only one weed i.e. horse purslane was not allowed to grow and interfere with maize plants for only 20 DAE and after which all weeds including horse purslane exhibited interference with maize plants produced shorter cobs (23.19 cm). It could be owing to interference ability of horse purslane and other weeds which collectively used more growth resources than plants of maize. Interestingly it was noted as evident from the data that plots where all weeds other than horse purslane were allowed to compete and interfere with maize could not vary significantly from those plots where all other weeds were controlled from growing and only horse purslane was allowed to interfere with maize plants. It is suggestive of the hypothesis that horse purslane alone is more aggressive than other prevalent weeds for their effect on maize growth. Our study is line with findings of (Buhler, 2002), who reported that significantly least cob length produced from the weedy plots could be attributable to the fact that it also produced the highest weed density and dry weed biomass.

Stem diameter (cm)

Stem diameter was significantly maximum (4.63 cm) in plots which were weed free whole season situation was imposed as there was no weed interference during the season and all the available resources (nutrients, water, space, light) were utilized by crop. Whereas significantly lowest stem diameter (2.45 cm) was reported in weedy check, all weeds kept plots (Table-1). Plots which were kept free from all weeds for 60 DAE exhibited better growth which was translated in improved stem diameter (4.32 cm). It could be owed to lack of weed crop interference for first 60 DAE creating favorable conditions for improved growth and development of maize plants. Stem diameter could not vary among the plots which were kept all weed free for 40 and 60 DAE. However, it was interesting to note that for the same durations i.e. 40 and 60 DAE horse purslane when kept free from plots revealed considerable differences (Table-1). This is again a reflection of the magnitude of damage caused due to increasing interference duration of horse purslane with maize crop. Further reduction is evident as interference duration increased gradually in plots where all weeds were restricted to grow only for the first 20 DAE and revealed lower stem diameter (3.40 cm). Sole horse purslane aggressivity is also evident for variation in plots where all weeds were controlled for first 20 DAE to those plots where only horse purslane was controlled for early 20 DAE (Table-1). it might be attributed to increased period of competition and interference between crop and weeds. Plots maintained for weedy check only horse purslane revealed as much damage extent on reduction in stem diameter as have been shown on stem diameter of maize plants in plots where all weeds other than horse purslane collectively reduced stem diameter. Stem diameter was severely reduced by this uncontrolled weed interference and allelopathic effect. Maize plant height and stem diameter were affected due to competition with Alexander grass and southern crabgrass weeds (Page *et al.*, 2010).

Kernel yield (t ha^{-1})

Statistically highest kernel yield 6.86 t ha^{-1} was recorded in plots where weeds free situation was imposed for whole season (Table-1). Kernel yield was maximum as the result of absence of competition between weed and crop which resulted in maximum uptake of growth resources by the crop. Significantly next maximum kernel yield (6.15 t ha^{-1}) was recorded in plots where interference of all weeds free for 60 DAE was allowed. It could be due to presence of favorable conditions for crop growth and development. Kernel yield of maize in all weeds free for 40 DAE maintained plots was higher than those plots where horse purslane was not allowed to interfere with maize plants for 60 DAE (Table-1). However, it was noteworthy that for the same duration where horse purslane was not allowed to grow for 40 DAE resulted in significant reduction in maize kernel yield. It can be related with presence of all other weeds during first 40 DAE. It reflects the importance of managing all the weeds inclusive horse purslane at 40 DAE of maize crop plants for better productivity. Plots maintained all weeds free for 20 DAE resulted in more damages to maize kernel yield than the plots where only horse purslane was kept controlled. It shows more additive damage on maize kernel yield by many weeds like purple nutsedge, fieldbind weed, common purslane and wild melon [*Cucumis melo agrestis* (Naudin.) Pangalo] etc. when compared with the sole horse purslane for initial 20 DAE. Whereas, the lowest kernel yield (3.83 t ha^{-1}) was found in plots where all weeds were allowed to grow. The lowest maize kernel yield was recorded as the result of unmanaged growth and development of weeds during whole season. Kernel yield (4.40 t ha^{-1}) in weedy check except horse purslane was highly affected by the un controlled and un managed growth of weeds most importantly during the critical growth stages of crop increased weed crop interference had negative effect on crop kernel yield (Table-1).

Stover yield (t ha^{-1})

Statistically second lowest kernel yield (4.15 t ha^{-1}) yield was reported in (weedy check only horse purslane) due to high infestation and allelopathic effects of horse purslane(Table-1). Our study is in agreement with Mubeen *et al*. (2009), who reported that minimum seed yield was recorded in plots where weeds were allowed to grow throughout the season. Statistically highest stover yield (10.20 t ha^{-1}) was achieved in the plots where weeds free whole season situation was maintained. Maximum stover yield obtained can be due to no interference between maize crop and weeds. Statistically next highest stover yield (10.00 t ha^{-1}) was reported in all weeds free 60 DAE treated plots as for most of the growing period weed crop competition was eliminated during crop growth and development. Stover yield of 9.86 t ha^{-1} was recorded in plots having all weeds free situation for 40 DAE. Weed crop interference period was increased as a result growth resources supply for crop was lowered. Stover yield (9.57 t ha^{-1}) in plots with horse purslane free for 60 DAE was higher than those plots where for the same period horse purslane was not allowed to interfere with maize plants. Likewise, similar trend for stover yield was also observed when all weeds interference and horse purslane interference was compared in field conditions for 20 DAE (Table-1).

Statistically lowest stover yield (3.85 t ha^{-1}) was recorded in plots where all weeds were allowed to grow and interfere with maize crop. Weedy check except horse purslane maintained plots had all other weeds growing resulted in increased interference. However, the reduction in stover yield was less in weedy check except horse purslane when compared with weedy check plots where only horse purslane was allowed to grow. It may be attributed to more number of weeds causing additive and cumulatively more damage. However, if we note the damage caused by individual weed, it is quite evident from the data that only horse purslane has single handedly caused marked reduction in maize growth and yield when compared with losses incurred by other individual weeds infesting the maize crop fields. Horse purslane infestation and its allelopathy could have the reducing effects on maize stover yield. This study is in agreement with the finding of Azhar (2009), who stated that minimum stover yield was recorded in high population of weeds.

Table-1. Effect of horse purslane interference on plant height, cob weight, cob length, stem diameter, kernel yield and stover yield of hybrid maize.

Treatments	Plant height (cm)	Cob weight (g)	Cob length (cm)	Stem diameter (cm)	Kernel yield (t ha^{-1})	Stover yield (t ha^{-1})
Weeds free (whole season)	178.49 a	339.33 a	28.72 a	4.63 a	6.86 a	10.20 a
Horse purslane free till 20 DAE	153.90 e	240.00 f	23.19 ef	3.36 cd	5.14 e	9.21 f
Horse purslane free till 40 DAE	162.04 d	274.67 d	25.15 cd	3.54 cd	5.63 c	9.45 e
Horse purslane free till 60 DAE	168.19 c	286.00 c	26.01 cd	3.90 bc	5.73 c	9.57 d
All weeds free 20 DAE	156.90 e	250.00 e	24.15 de	3.40 cd	5.35 d	9.26 f
All weeds free 40 DAE	168.83 c	297.33 b	26.46 bc	4.12 ab	5.98 b	9.86 c
All weeds free 60 DAE	173.51 b	302.67 b	28.12 ab	4.32 ab	6.15 b	10.00 b
Weedy check (all weeds except horse purslane)	140.07 f	226.67 g	23.13 ef	3.17 d	4.40 f	4.35 g
Weedy check (only horse purslane)	134.01 g	222.67 gh	23.06 ef	3.02 de	4.15 g	4.02 h
Weedy check (all weeds)	125.95 h	219.33 h	21.50 f	2.45 e	3.83 h	3.85 i
Tukey's Honestly Significant Difference ($HSD_{0.05}$) Value	3.9376	5.8608	1.9407	0.5781	0.1995	0.0697

Crop Growth Rate ($g\ m^{-2} d^{-1}$)

Crop growth rate (CGR) was recorded highest during the period of 60-75 days after emergence (Fig. 1). At 60-75 days period, maximum CGR of 47.52 g m^{-2} d^{-1} in weeds free whole season kept plots Weed free whole season was followed closely by plots which were kept all weeds free for 60 DAE (46.62 g m^{-2} d^{-1}). In all weeds free plots for 40 DAE CGR of 44.16 g m^{-2} d^{-1} while in horse purslane free plots for 60 DAE 41.20 g m^{-2} d^{-1} was recorded, respectively. It was followed by CGR of 39.01 g m^{-2} d^{-1} in plots which were kept horse purslane free for 40 DAE. All weeds free kept plots for 20 DAE revealed relatively better CGR of maize when compared with weedy check plots of sole horse purslane. Minimum CGR of 17.66 g m^{-2} d^{-1} was recorded in plots where no weed was controlled at all. Next minimum crop growth rate was reported in (weedy check only horse purslane) which resulted in 29.78 g m^{-2} d^{-1} while in (weedy check except horse purslane) CGR was 34.39 g m^{-2} d^{-1} (Fig. 1)

Statistically maximum crop growth recorded in weed free plots for whole season could be owing to the fact that crop weed interference was eliminated by hand weeding as a result of which all the growth resources were utilized by crop only and there was no limitation in nutrient availability at critical period of crop growth and development. Crop growth rate was significantly lowest in weedy check all weeds, as some weeds namely (purple nutsedge, false amaranth, common purslane) were present at early stage and other weeds (fieldbind weed, wild melon) infested the field during lateral growth stages. While some were even growing and present at harvest of maize crop (purple nutsedge and wild melon). Therefore, presence of weed/s at all stages of crop growth and development till harvest broaden the interference spectrum of weeds with maize crop thereby reducing the CGR to minimum. As weeds are better utilizer of growth resources at initial crop growth stages, limited availability significantly affects crop growth and development. This study is similar to the results of, weed free (control) resulted in maximum crop growth rate (Lindquist *et al.*, 2005; Rajcan and Tollenaar, 1999).

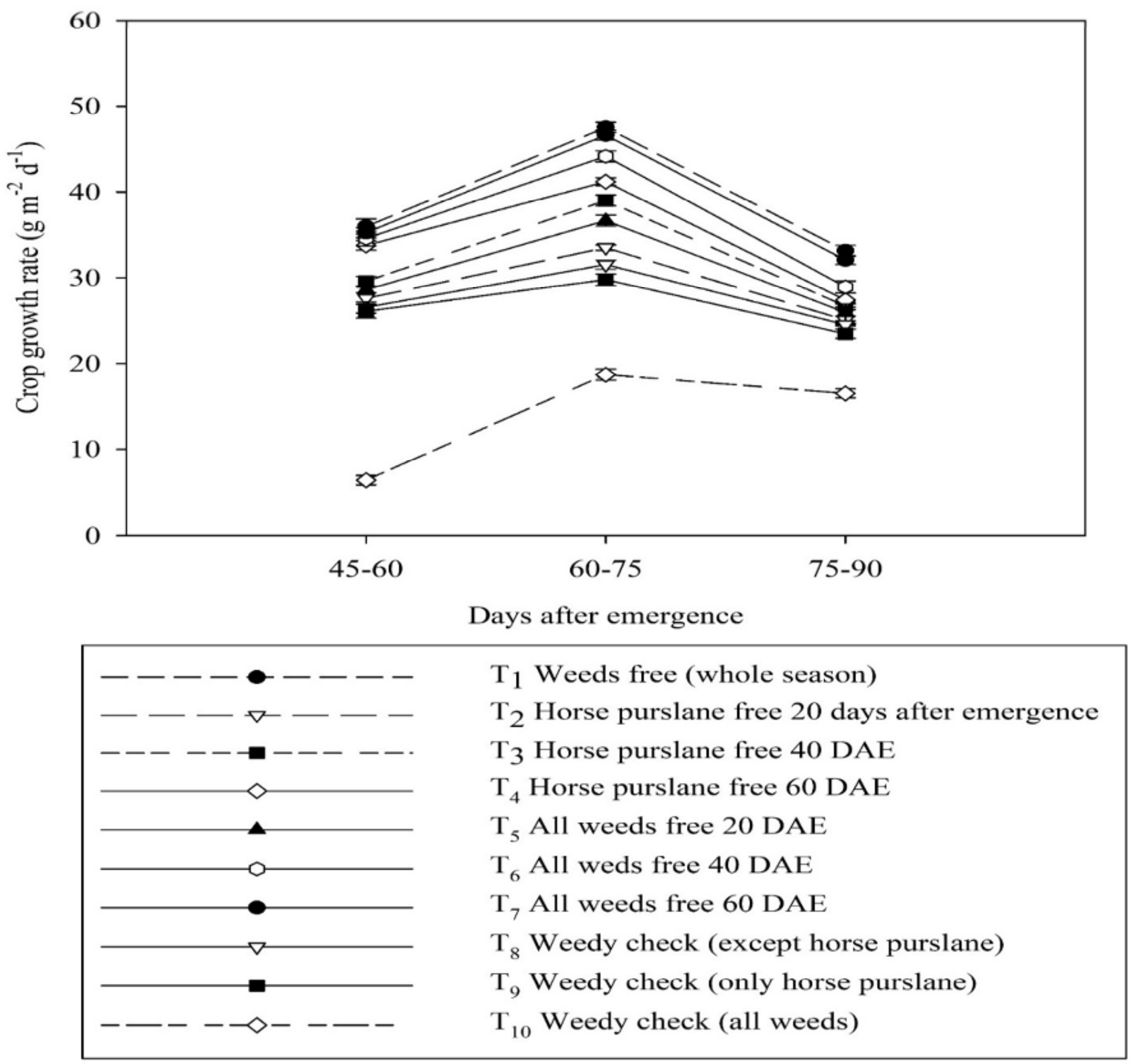

Fig 1. Crop growth rate during growing season of autumn maize

Leaf Area Index (LAI)

Maximum LAI was achieved in plots maintained weeds free for whole season. There was a gradual increase in LAI in all treatments till 75 DAE but the data recorded revealed that at 90 DAE, there was decrease in LAI in each treatment which means that leaf area began to decrease 75 DAE (Fig. 2). This may be attributed to the reason that crop started to shift to its maturity and at 90 days crop life cycle was completed. At 75 days maximum LAI (4.45) reported in those experimental plots where weeds were not allowed to grow throughout the entire season. Second highest LAI (3.98) was reported in experimental units where all weeds were restricted to interfere for 60 DAE which was followed by LAI (3.92) in all weeds free ensured plots for 40 DAE. Plots where maize faced horse purslane interference for 40 DAE could not bring significant variation when compared with horse purslane free 60 DAE. Similar trend of interference for LAI was also observed among the treatments viz all weeds free 20 DAE and horse purslane free 20 DAE (Fig. 2).

Lowest LAI was recoded in plots where all weeds interfered with maize crop till harvest Weedy check only horse purslane plots could not vary significantly from weedy check except horse purslane employed plots. Outcome of competition between weeds and crop for full season and row spacing of 75 and 55 cm reduced the LAI significantly (Maqbool *et al*., 2006).

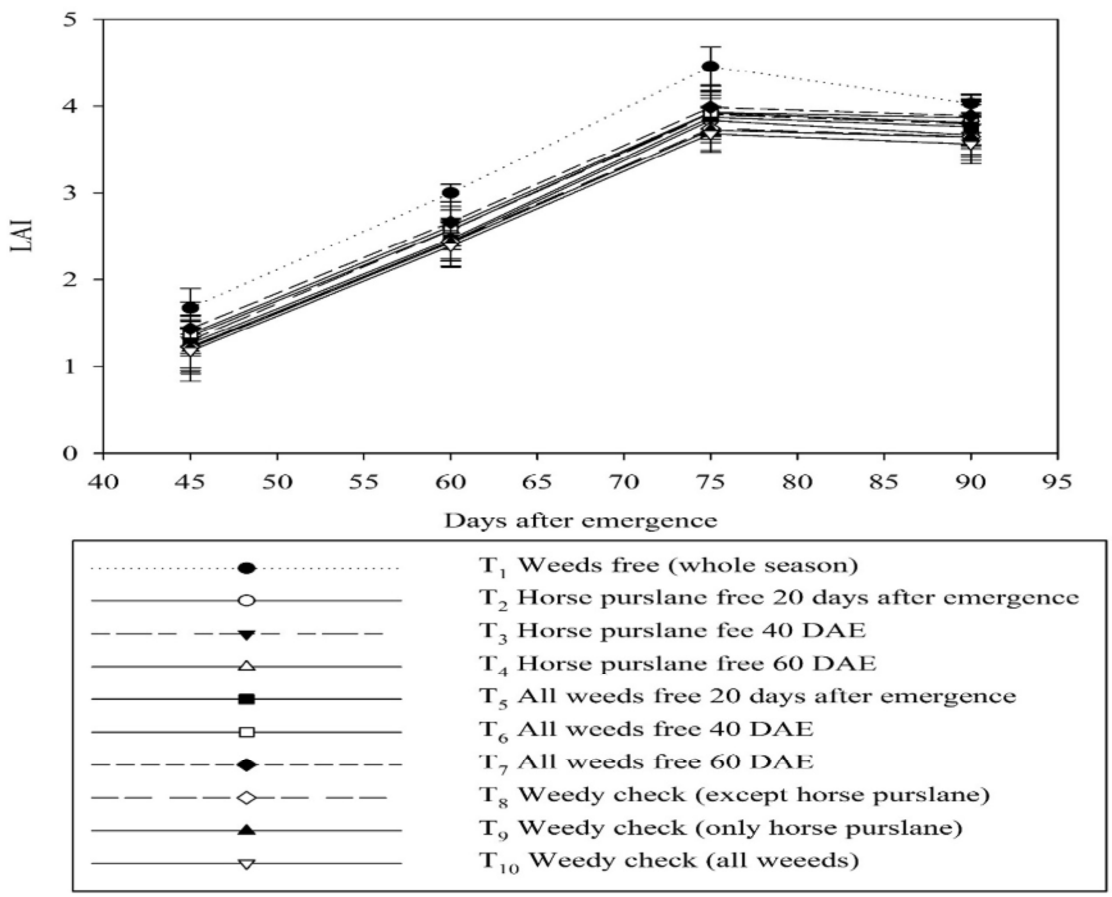

Fig. 2. Leaf area index during growing season of autumn maize.

Net Assimilation Rate (NAR) ($g\ m^{-2} d^{-1}$)

NAR of crop was also significantly affected by the treatments used in the study. Highest NAR of 6.57 g m^{-2} d^{-1} was reported in weeds free whole season. Next maximum NAR of 6.43 g m^{-2} d^{-1} was reported in plots where all weeds were removed manually for 60 DAE. NAR was 5.79 and 5.67 g m^{-2} d^{-1} in plots where horse purslane were kept controlled for 60 and 40 DAE, respectively. All weeds free 20 DAE ensured plots resulted in NAR of 5.54 g m^{-2} d^{-1} which was slightly better than the NAR of 5.45 in experimental units where horse purslane was manually kept from growing for 20 DAE. Weedy check all weeds plots resulted in lowest NAR of maize (4.09 g m $^{-2}$ d^{-1}). Weedy check except horse purslane and weedy check only horse purslane resulted in NAR of 5.55 g m $^{-2}$ d^{-1} and 5.31 g m $^{-2}$ d^{-1}, respectively (Fig. 3). This finding is in line with the study of (Randhawa, 2012) who stated that low levels of weed densities resulted in higher NAR of maize.

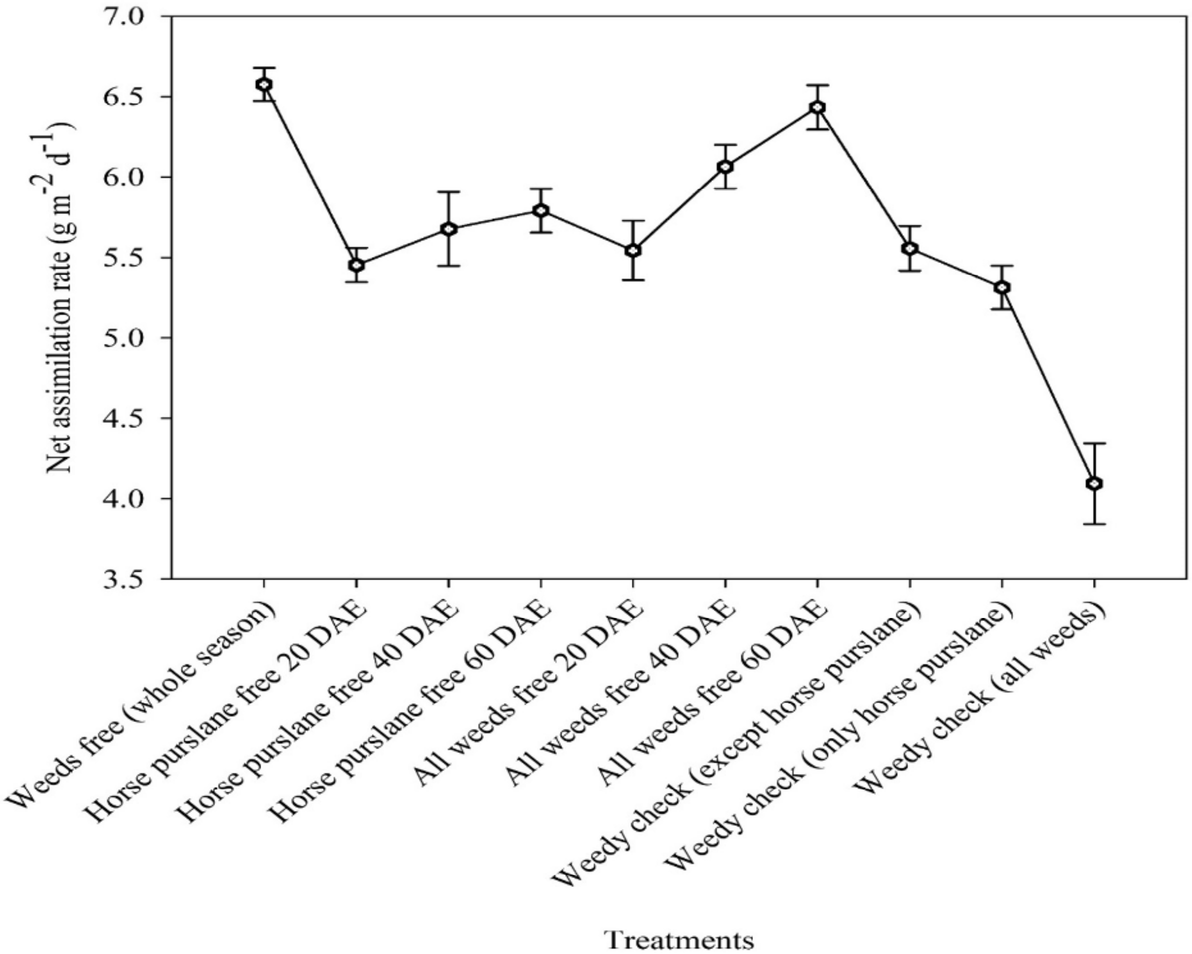

Fig. 3. Net assimilation rate during growing season of autumn maize.

Leaf Area Duration LAD (days)

Maximum LAD (190.98) at 90 days was recorded in weeds free whole season maintained plots. Plots in which no weed was allowed to grow for 60 DAE showed a LAD of 177.26 was reported (Fig. 4). Whereas plots having all weeds free condition for 40 DAE also could not reach level of significance with all weeds free 60 DAE treated plots. Horse purslane free 60 and 40 DAE could not vary with each other for LAD. Similarly plots of maize where all weeds were manually controlled for 20 DAE could not vary a great deal with maize crop plots where horse purslane was limited in first 20 DAE. Weedy check all weeds showed minimum LAD (163.07). Leaf area duration could not bring significant differences between weedy check only horse purslane treated plots and weedy check except horse purslane maintained plots (Fig. 4). These findings are similar to the study of Irshad *et al.* (2002), who reported that maximum leaf area duration (136.85 days) was achieved in plots having no weed competition after transplantation and the leaf area duration decreased as the competition increased

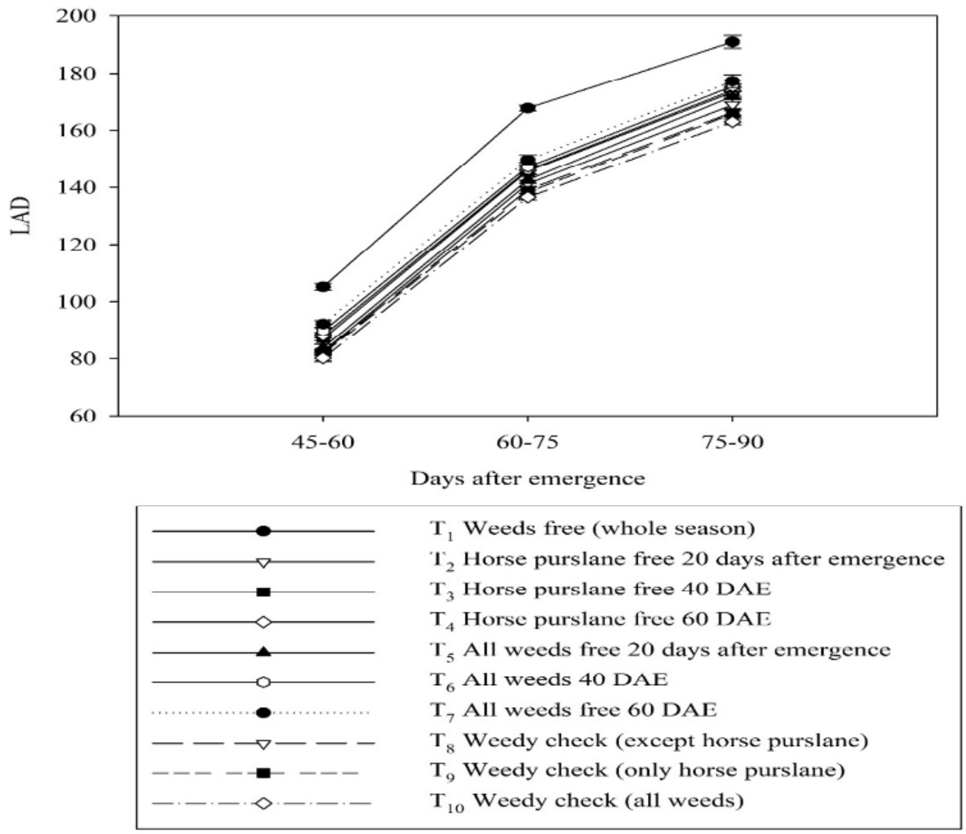

Fig. 4. Leaf area duration during growing season of autumn maize.

Horse purslane density (m^{-2}) at 30, 45 and 60 DAE

After 30 days of emergence of maize plants, horse purslane density was at quick rise and horse purslane started developing flowers. After 45 days of emergence, field was completely covered by horse purslane as its density was maximum under environmental conditions favorable for its growth and development at this period (Fig. 5). Flowers were completely developed and horse purslane was at seed production stage and its life cycle was completed at 60 DAE. Density of horse purslane at 45 DAE was maximum 16.00 m^{-2} in T_9 (weedy check only horse purslane) and it was followed by density of 8.67 m^{-2} in treatment T_{10} (weedy check all weeds). Horse purslane growth and development was maximum at that point of time and ground was covered by horse purslane growth. This was mainly due to its growth pattern and abundant supply of available resources. Whereas plots where all weeds were controlled through hand weeding for 20 DAE and the plots in which horse purslane was not allowed to grow for 20 DAE resulted in horse purslane population of 6.00 m^{-2}.

Data recorded at 60 days after emergence showed decrease in horse purslane density (Fig.5). Horse purslane utilized the available resources more effectively as compared to maize plants could be attributed to higher aggressiveness of this weed. This study is similar to finding of (Naeem *et al*., 2016), Maximum density of *T. portulacastrum* L. was recorded at 45 DAS.

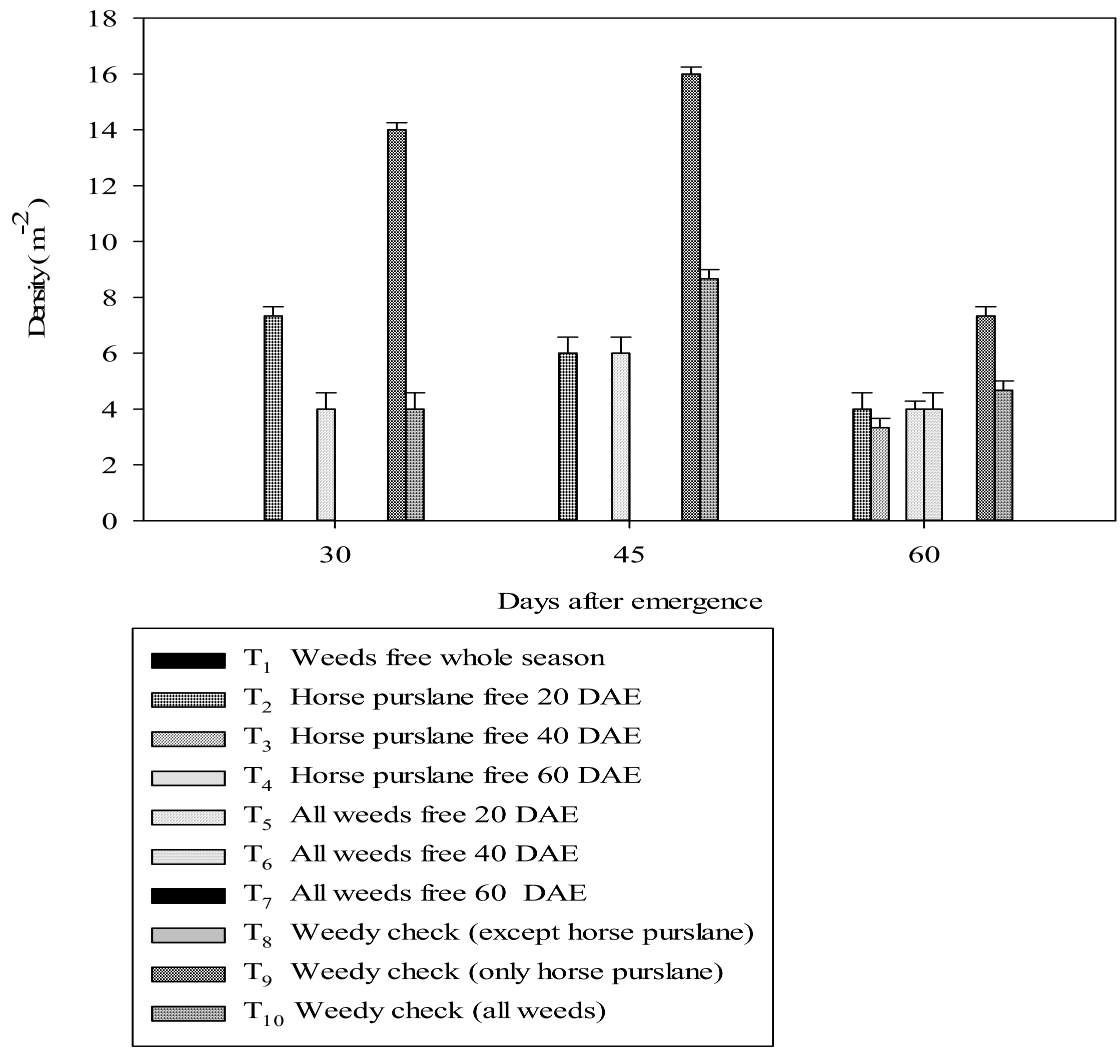

Fig. 5. Horse purslane density at 30, 45 and 60 DAE of autumn planted maize as influenced by horse purslane interference.

Horse purslane dry weight (g m^{-2}) at 30, 45 and 60 DAE

After 30 days of emergence, horse purslane dry weight was increasing rapidly as its growth and development was also high during this period as a result of which nutrient and other resources uptake was also high. However, horse purslane dry weight was maximum after 45 days of emergence, maximum uptake of nutrients and all other available resources might have taken place during this period as a result of which maximum biomass of horse purslane was produced. Dry weight of horse purslane was maximum 78.40 g m^{-2} in plots where horse purslane was not controlled throughout the entire season. It was followed by dry weight of 36.04 g m^{-2} in experimental plots where all weeds were allowed to interfere till crop harvest. It is suggestive of the fact that among all weeds at this stage (45 DAE) horse purslane dry weight was dominant. It is noteworthy that in plots with horse purslane biomass was higher when it was controlled to grow for first 20 DAE when compared with sole horse purslane limited to grow for same 20 DAE. After 60 days of emergence, horse purslane biomass started to decline as it was completing its lifecycle (Fig. 6).

Horse purslane dry weight was at increasing trend after 30 days of emergence and reached maximum after 45 days of emergence. It shows that optimum quantity of available resources was utilized by horse purslane during this period as a result of which weed growth and development was maximum. This study is against the findings of (Naeem et al., 2016), he reported that horse purslane dry biomass was maximum at 60 DAS

Horse purslane density and dry weight was recorded maximum during the period of 30-45 days after emergence, which means both environmental and field conditions were optimum for its growth and development at that period and at 60 days after emergence decrease in horse purslane density was recorded which indicates that horse purslane was reaching at maturity. So there is need to control horse purslane within 45 days of crop emergence but its control within 30-45 days of crop emergence is more suitable as horse purslane growth and development is most aggressive during this specific duration. In addition to this, presence of growth resources in abundance (soil moisture and nutrients) could have also played an important role in robust growth of horse purslane.

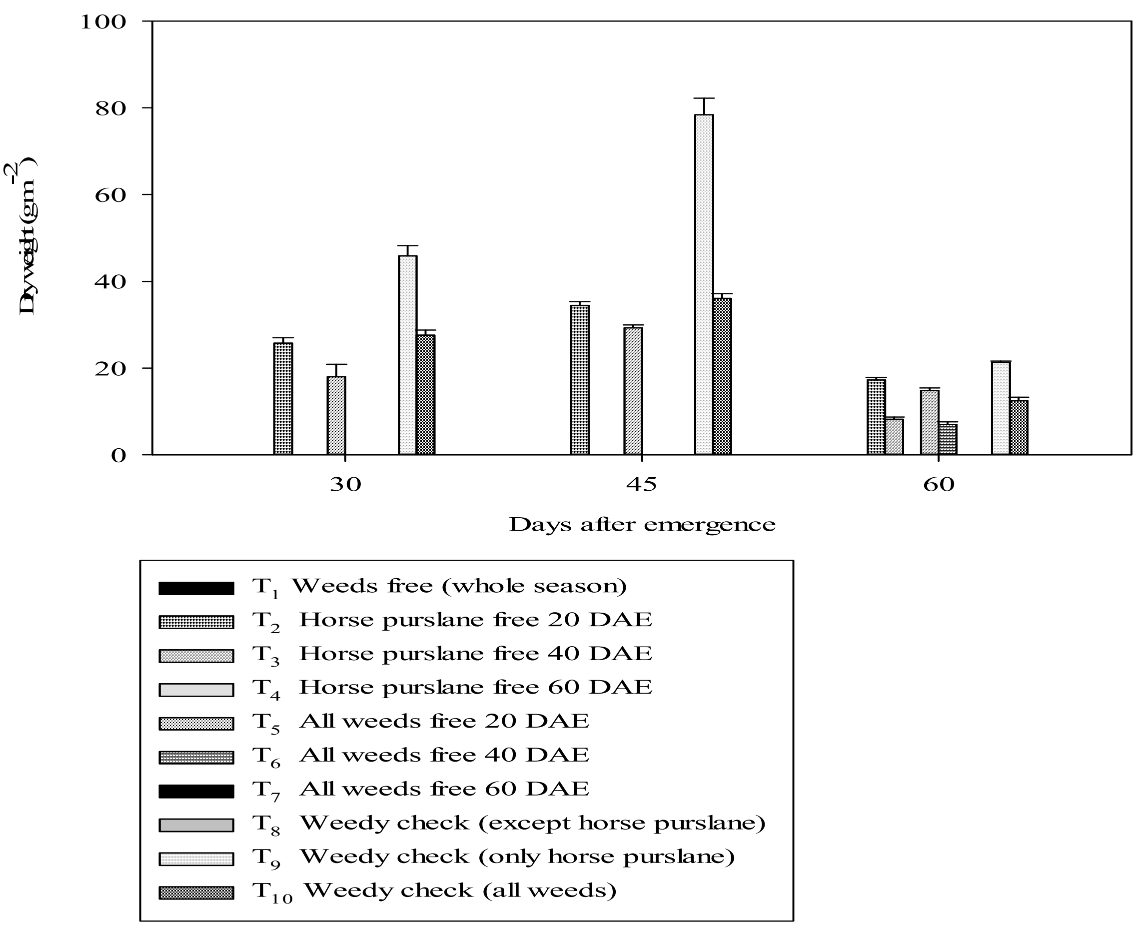

Fig. 6. Horse purslane dry weight at 30, 45 and 60 DAE of autumn planted maize as influenced by horse purslane interference.

Total weeds density (m^{-2}) at 30, 45 and 60 DAE

Collectively maximum number of weeds were present in the field during the period of 30-60 DAE. At 45 days after emergence density of total weeds was maximum as most the weeds present in the field were at flowering and seed production stage. After 45 days of emergence, total weed density in plots in which horse purslane was not allowed to interfere for 20 DAE was 24.66 m^{-2} and in plots where horse purslane was kept controlled for 40 DAE density of total weeds was 17.00 m^{-2} (Fig. 7). Total weeds population of 18.00 and 22.66 m^{-2} was reported in horse purslane free plots for 60 DAE and all weeds free for 20 DAE, respectively. In Weedy check except horse purslane maintained plots total weeds density was 20.66 m^{-2} whereas in plots-weedy check only horse purslane plots total weed density was 16.00 m^{-2}. In treatment (Weedy check all weeds) total weeds density was 19.33 m^{-2}. After 60 days of emergence, density of total weeds was reduced which indicates that most of the weeds were approaching maturity and life cycle completion. By using the data, we can say that weeds growth and development started to rise after 30 days of emergence and was maximum between 45-60 days interval due to the presence of optimum climatic conditions and availability of maximum amount of nutrients and all other resources. It also indicates lifecycle of most of weeds with higher infestation level in maize fields and supports the idea of synergy of the weeds which not only threatens the maize productivity at individual weed level but also acting collectively to diminish the crop growth and development through interference. This study is quite in line with study of Seyyedi *et al*. (2016), maximum density of total weeds was recorded at 42 days after seedling emergence.

Total weeds dry weight (g m^{-2}) at 30, 45 and 60 DAE

Collectively total weeds dry weight was maximum during the interval of 30-45 days after emergence. At 45 days after emergence dry weight of total weeds was maximum as all the weeds present in the field were at flowering and seed production stage. As a result of which maximum uptake and utilization of available resources and nutrients took place during this period. After 45 days of emergence, total weed dry weight in horse purslane free plots for 20 DAE was 34.23 g m^{-2} and in horse purslane free plots for 40 DAE dry weight of total weeds was 18.68 g m^{-2} (Fig. 8). Dry weight of total weeds 19.87 g m^{-2} and 28.39 g m^{-2}, respectively was reported in plots with horse purslane free situation for 60 DAE and all weeds free kept plots for 20 DAE, respectively. In plots where all other weeds other than horse purslane were present throughout the season, dry weight of total weeds was (26.89 g m^{-2}) whereas in weedy check only horse purslane maintained plots total weed dry weight

Total weeds dry weight (g m^{-2}) at 30, 45 and 60 DAE

Collectively total weeds dry weight was maximum during the interval of 30-45 days after emergence. At 45 days after emergence dry weight of total weeds was maximum as all the weeds present in the field were at flowering and seed production stage. As a result of which maximum uptake and utilization of available resources and nutrients took place during this period. After 45 days of emergence, total weed dry weight in horse purslane free plots for 20 DAE was 34.23 g m^{-2} and in horse purslane free plots for 40 DAE dry weight of total weeds was 18.68 g m^{-2} (Fig. 8). Dry weight of total weeds 19.87 g m^{-2} and 28.39 g m^{-2}, respectively was reported in plots with horse purslane free situation for 60 DAE and all weeds free kept plots for 20 DAE, respectively. In plots where all other weeds other than horse purslane were present throughout the season, dry weight of total weeds was (26.89 g m^{-2}) whereas in weedy check only horse purslane maintained plots total weed dry weight
was 52.84 g m^{-2}. In weedy check all weeds kept plots dry weight of total weeds

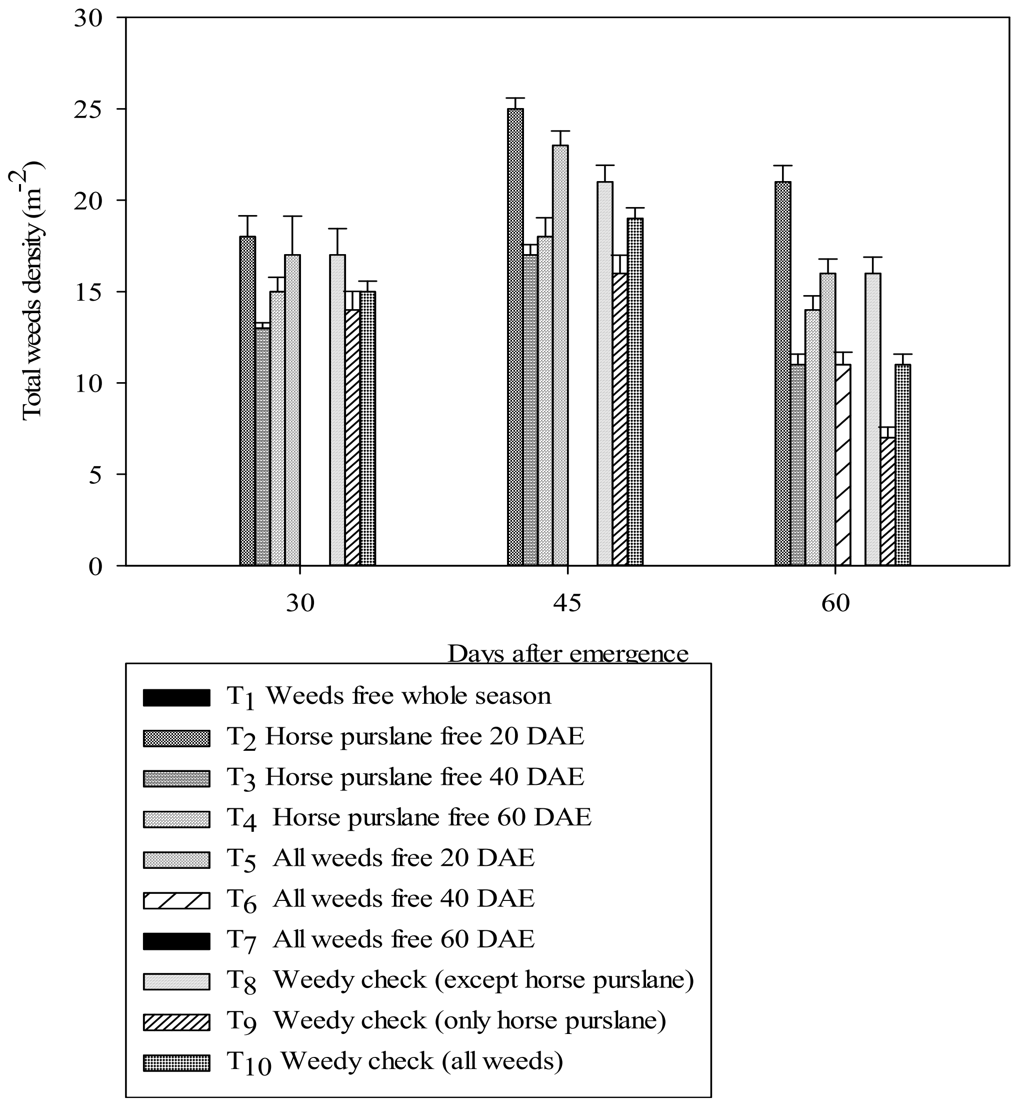

Fig. 7. Total weed density at 30, 45 and 60 DAE of autumn planted maize as affected by horse purslane interference.

was 29.15 g m^{-2}. After 60 days of emergence, total dry weight of weeds was reduced as compared to earlier days which shows that weed life cycle was near completion. Dry weight of all weeds was maximum after 30-60 days of emergence. This data indicates the resources uptake nature of all weeds collectively. By using this data we can also determine growth nature and optimum growth of all the weeds as different growth habits were adopted by weeds in the field. This data gives us a view about the optimum period of weeds growth and competition. This study is quite in line to the study of Akhtar *et al*. (2000) also found that increasing weed crop competition duration increased weed biomass.

Rapid rise in horse purslane density was observed at 30 DAE and flower initiation was also observed at this point in horse purslane whereas total weed density was also at 30 DAE as growh and development of all weeds was increased at this point along horse purslane growth of weeds like false amaranth, common purslane and purple nutsedge was high.

Maximum density of horse purslane was reported at 45 DAE (Fig. 8), field was covered with horse purslane as the result of quick growth and suppressing nature of horse purslane. Horse purslane flowers were completely developed and production of seeds was also reported. Total weeds density was also maximum at 45 DAE, conditions were suitable for the growth of all weeds at 45 DAE in addition to this growth of weeds like (wild melon and fieldbind weed) was also incresed.

At 60 DAE, total weed density was high as compared to horse purslane density as growth and development of wild melon and fieldbind weed was the maximum at this stage, perennial weed presence also contributed at this point. Decrese in horse purslane density was reported at 60 DAE as its growth was completed and it was reaching maturity, matured horse purslane seeds were at dispersal stage.

Increase in horse purslane dry weight at 30 DAE was recorded whereas dry weight of total weeds was also increased at that particular point of time. Horse purslane and total weed dry weight was maximum at 45 DAE, which shows that both soil and atmospheric conditions were highly favorable for biomass accumulation. Decrease in dry biomass of horse purslane and total weeds was reported at 60 DAE, which indicates that most of the weeds were reaching maturity which led to decrese in biomass accumulaton. Horse purslane density was maximum at 30-45 DAE as compared to plots where total weed density was maximum at 45-60 DAE as some weeds (wild melon and fieldbind weed) emerged at later stage. Dry weight of horse purslane sole and total weeds collectively was maximum at 30-45 DAE.

Maize kernel yield was maximum in all weeds free (whole season) whereas reduction of maize kernel yield was observed in plots where weeds were controlled for 20 and 40 DAE as compared to plots where weeds were controlled for 60 DAE. Similarly kernel yield of horse purslane free 60 DAE was high in compariosn to kernel yield recorded in horse purslane free 20 and 40 DAE. Weedy check (all weeds) resulted in lowest kernel yield which was followed closely by kernel yield in weedy check (only horse purslane) and weedy check (except horse purslane) respectively. This study is familiar with the results of Ugalechumi *et al.*, 2018. They reported that horse purslane infests maize heavily, causing enormous yield losses and threatens the sustainability of maize production.

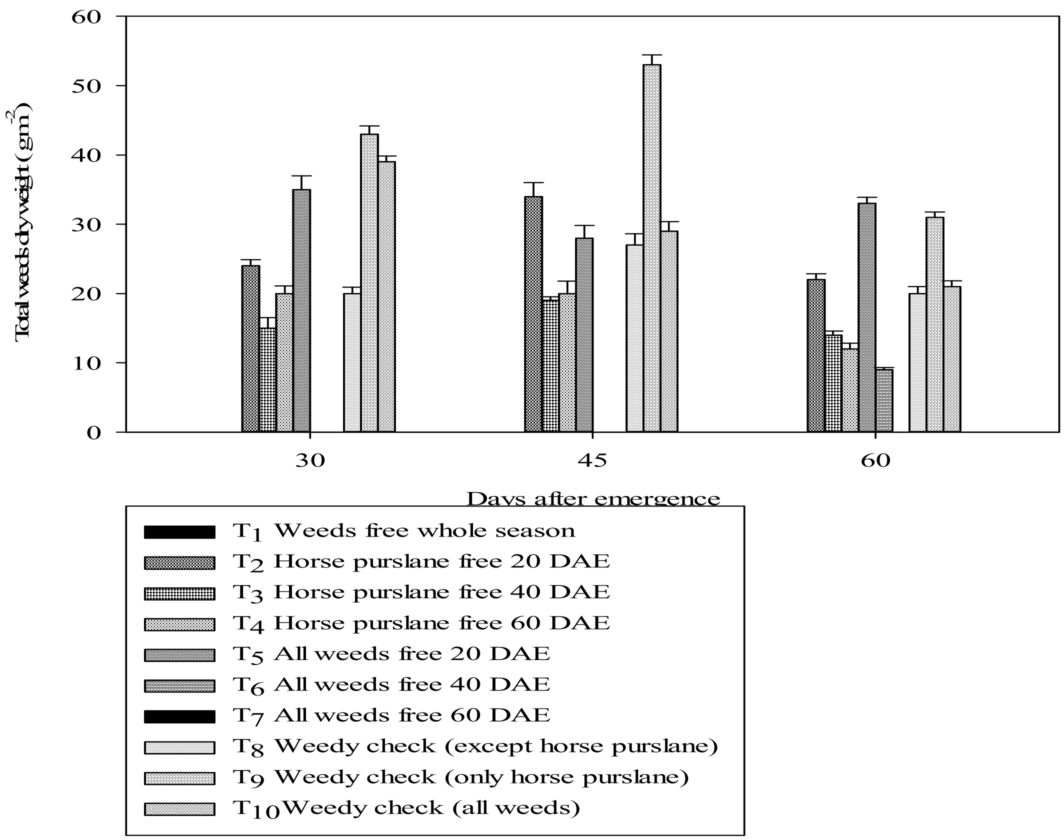

Fig. 8. Total weed dry weight at 30, 45 and 60 DAE of autumn planted maize as influenced by horse purslane interference.

Yield increase (%) over Weedy check (all weeds)

Comparison for the increase in yield in all treatments employed during study as compared to weedy check (all weeds) show that maximum increase in yield was recorded in weeds free whole season plots. Weeds were controlled for the whole season and as a result all the growth resources were available for crop which resulted in optimum crop growth and development. As compared to weedy check all weeds kept plots kernel yield obtained in weeds free whole season situation was 79.13 % high (Fig. 9). Next maximum increase in yield was achieved in all weeds free 60 DAE plots, kernel yield obtained in (all weeds free 60 DAE condition was 60.60 % greater than the kernel yield observed in weedy check all weeds plots. All weeds free situation for 40 DAE, resulted in kernel yield which was 56.24 % greater than kernel yield achieved in weedy check all weeds plots. Kernel yield in horse purslane free kept plots for 60 DAE was 49.73 % more than plots having weedy check all weeds condition. In horse purslane free maintained plots for 40 DAE, kernel yield was 47.11 % higher than the kernel yield in weedy check all weeds ensured plots. But as compared to kernel yield in weedy check all weeds plots the kernel yield in all weeds free 20 DAE was 39.72 % higher. Kernel yield in horse purslane free kept plots for 20 DAE was 34.32 % high. Kernel yield in weedy check except horse purslane plots in comparison to weedy check all weeds plots, kernel yield was 15.06 % greater in plots where weedy check only horse purslane treatment was imposed horse purslane growth was most aggressive. Horse purslane had reducing effect on crop growth and yield. As compared to plots kept weedy all weeds kernel yield obtained from weedy check only horse purslane plots was 8.37 (%) greater. Saeed *et al*., 2010 reported higher yield losses of 29.5 and 30.2% were recorded in plots having higher weed density of 18 plants m^{-2} (Fig. 9)

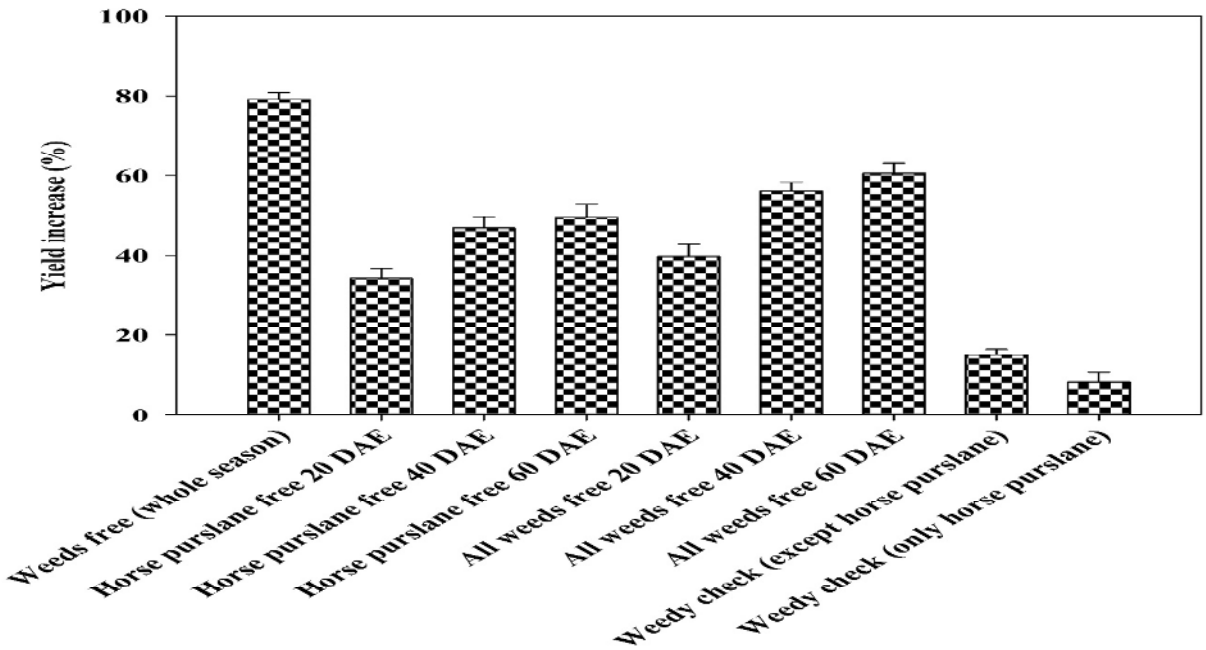

Fig. 9. Percentage increase in kernel yield over weedy check (all weeds) in autumn planted maize as influenced by horse purslane interference.

CONCLUSIONS

Kernel yield from plots where horse purslane was hand weeded for 60 DAE revealed 49.73 % higher than the weedy check where all weeds were removed. It may be concluded that in fields with high infestation history of horse purslane farmer should keep a close look on weeds including horse purslane and should control the horse purslane within first 45 days in maize field not only to avoid the interference from this problematic weed but to obtain higher maize kernel yield.

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