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Original Research Article

Response of Weed parameters, phenology and growth attributes of Maize to Plant Density and Weeding Frequency at Assosa District, Benishangul Gumuz Regional State, Ethiopia

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Abstract

Maize (Zea mays L.) is staple food crop grown in Benishangul Gumuz regional state of Ethiopia. However, its productivity is constrained by a number of problems out of which weed management and plant density is the most important ones. The experiment was conducted to determine effects of plant densities and weeding frequency on weed Control and productivity of maize in 2016 main cropping season at Assosa district, Ethiopia. Four levels of weeding frequency (no, one, two and completely weed free) and four plant densities [31250 plants ha^{-1} (80 cm x 40 cm and one seed per hole), 44444 plants ha^{-1}(75 cm x 30 cm), 53333 plants ha^{-1}(75cm x 25cm) and 62500 plants ha^{-1}(80 cm x 40 cm and two seeds per hole)] laid out in a randomized complete block design with factorial arrangement in three replications.Main effects of weeding frequency and plant densities significantly ($P \leq 0.05$) affected most of the measured phenological and growth parameters of maize. The dominant weed flora infesting maize field during growing season were Cyperusrotundus, Guizotia scabra, Eleusine indica and Hyparrhenia hirta. Higher leaf area (5628 cm^2) and leaf area index (2.68), were achieved in twice hand weeded fields. significantly higher plant height (224cm) was obtained from completely weed free plots. Higher plant height (224 cm) and leaf area index (3.2) were obtained from the highest plant density of 62500 plants ha^{-1}. There was also significant interaction effect of weeding frequency and plant density on weed density, weed dry matter and weed control efficiency. The higher weed density (221) and weed dry matter (741 g m^{-2}) were obtained at weedy check and lower populated (31250) plants ha^{-1} of maize. Thus, practicing of twice hand weeding and a plant density of 53333 plants ha^{-1} (75cm x 25 cm) was found to be better to variety BH-546 production in Assosa area.

Keywords: Plant density, Weeding frequency, dominant weed

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops in Ethiopia of East Africa where it is a staple food (Tolessa *et al*., 2001).It ranks 2ndafter teff (*Eragrotis tef*) in area coverage but stood first in total national production and yield per hectare (CSA, 2016). Considering its importance in terms of having wider adaptation, higher total production and higher productivity, compared to other crops, maize has been selected as one of the high priority crops to feed the ever-increasing human population of Ethiopia. Maize yields under farmers' conditions in the region average 3.38 t ha^{-1} or less than 62% of the potential yield of 5.5 t ha^{-1} (CSA,2016) under rainfed conditions. The agroecologies found in Benishangul Gumuz Region allows for several crops production and maize the main demand driven commodity in the area due to the ample rainfall and conducive environment for its production. Maize production in the region covers an area of about 45,278.92 hectares of land with productivity of 3.56 t ha^{-1}. In Assosa Zone, it was produced on 11,638.06 ha^{-1} of land in 2015/16 cropping season with a low productivity of 2.83 t ha^{-1} (CSA, 2016). A number of biotic and abiotic factors contribute to low productivity of maize. There includes the use of inappropriate agronomic practices (improper planting density, poor weed management, inappropriate sowing dates, inappropriate variety, poor soil fertility managements, limited use of inputs, etc.), drought, declining of soil fertility, and other factors such as lack of credit facilities, disease and insect pests (CIMMYT, 2004). Consequently, maintaining appropriate plant populations and weed management are one of the main challenges in maize production.

Plant density plays an important role in the competitive balance between weeds and maize. Singh and Singh (2006) stated that the weed density and other measures of weed abundance usually decrease as crop density increases. It affects most growth parameters of maize even under optimal growth conditions and it is considered a major factor determining the degree of competition between plants (Sangakkara *et al*., 2004). Ahmed *et al.* (2010) reported that plant density exerts a strong influence on maize growth, because of its competitive effect both on the vegetative and reproductive development. Andrade *et al*. (2002) reported that leaf area index and distribution of leaf area within a maize canopy are major factors determining total light interception, which affects photosynthesis, transpiration, and dry matter accumulation. Sani *et al*., (2008) concluded that plant height and leaf area index were significantly increased by increasing maize plant density from 38,000 to 66,000 plants ha^{-1}. Acciares and Zuluaga (2006) reported that a greater photosynthetic photon flux density interception with a lower weed above ground dry matter in narrow row arrangement was obtained. Similarly, Mashingaidze *et al*. (2009) showed that increasing maize plant density significantly decreased weed density and weed biomass. The total number of weed and dry weight of weeds significantly decreased by increasing plant density from 40,000 to 60,000 plants ha^{-1} of maize (Fanadoz *et al*., 2010).

Weeds are considered as a major problem in most maize fields and seriously causing reduction on maize yield and productivity. Maqbool *et al*. (2006) indicated that weed population and biomass in all weed-crop competition durations was significantly higher than weed free crop and they contribute the loss of maize growth parameters and the competition for plant nutrient reached 44%.The integrated effect between plant density and weed control management had a positive effect on weed parameters (Maqbool *et al*., 2006). Weeds poses an antagonistic effect on crop stand establishment and can compete nutrient and water with the crop, which ultimately affect productivity and quality of the crop.

There are different recommendations of plant density and weeding frequency. A plant densityof 53,333plants ha^{-1} was reported optimum for maximum growth parameters of maize (Iken and Amusa, 2004). In Ethiopia, the recommended spacing of 75cm and 30 cm between rows and plants, respectively isused, in maize which is 44,444 plants ha^{-1} (EARO, 2004). However, the Ministry of Agriculture and natural resource (MoANR) with Agricultural Transformation Agency (ATA) advocated the use of 62,500 plants ha^{-1} through its extension program (ATA, 2013). On the other hand, survey conducted on 700 farmers indicate that the majority of farmers on average maintain only 52% the plant population recommended by MoANR. Therefore, these different planting density and weeding frequency effects on the phenology and growth of maize crop is not well studied and documented. If plant density affects weed growth or not, it needs to be investigated.

At Assosa information on the optimum agronomic practice such as optimum weed management and plant density in maize pheonology and growth is not available. Thus, the present investigation was proposed with the objectives of determining the economic optimum weeding frequency and plant population on weed parameters, phenology and growth of maize, to investigate if there is interaction effect of weed management and plant population.

MATERIALS AND METHODS

Description of the experimental site

The experiment was conducted at Assosa Agricultural Research Centre under on station conditions during the 2016 main cropping season. Assosa is one of the research centers of the Ethiopian Institute of Agricultural Research (EIAR) located at about 670 km West from Addis Ababa, the capital city of Ethiopia. It has an altitude range of 1552 to 1580 m.a.s.l and lie in a geographic coordinate of 10^{o}02′57'' N latitude and 34^{o}33'26''E longitudes. It is characterized by hot humid agro-ecology having mean annual rainfall of 1316 mm per annum. The minimum and maximum temperature of the area was 16.03^{O}C minimum and 31.02^{O}C, respectively. The predominant soil type is Nitisols (AsARC, 2014). Figure 1

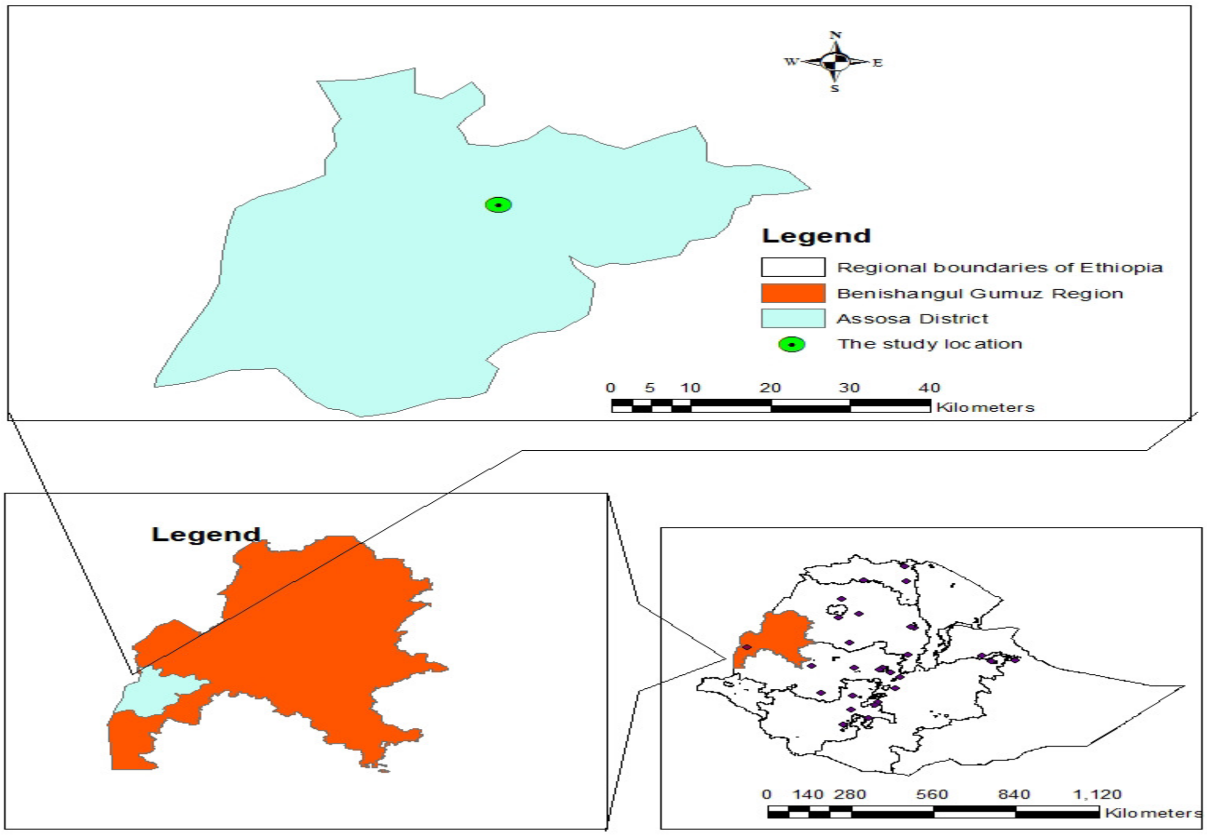

Figure 1. Map of the study area

Treatment set-ups

Four levels of plant population 53,333 (75 cm x 25 cm single seed per hole), 44,444 (75 cm x 30 cm single seed per hole), 62,500 (80 cm x 40 cm and two seeds per hole 5 cm apart) and 31,250 (80 cm x 40 cm and one seed per hole) and four weeding frequencies (weedy check, completely weeding (4 times), once weeding at 1st top dressing (weeding at 4 leaf stage) and twice weeding (at 1st and 2nd top dressing i.e. weeding at 4 leaf and the knee height stages) were factorially combined to make a total of 16 treatments. The treatments laid out in RCBD design in three replications. A hybrid maize variety BH-546 was used as a test crop.The plot size was 4.5 m x 4 m. Spacing between plots and replications was 1 m and 1.5 m, respectively. Four central rows were considered as net harvestable plot.

Data Collected

Weed data

Dominant weed species were collected and identified by using colored picture manuals.

Weed population

The category wise (broadleaved, grass and sedges) population count was taken with the help of 0.25m x 0.25m quadrate thrown randomly at two places in each plot and was identified and converted to population/density per m^2 while recording weed population the above ground biomass also was harvested within each quadrate.

Weed biomass

While recording weed population the biomass was harvested from each quadrate. The harvested weeds were placed into paper bags separately and dried in oven at a 65°C for 24 hours till constant weight was obtained and subsequently the dry weight was measured and converted in to g m^{-2}.

Weed control efficiency (WCE)

It was calculated using the weed dry matter weight per treatment on the basis of formula by *Patel et al.* (2006) as:

$$WCE = \frac{WDC - WDT}{WDC} * 100$$

Where: WDC= weed dry matter in weedy check,
WDT= weed dry matter in a treatment

Phenological data

Days to 50% tasseling

It was recorded as number of days from planting to when 50% of the plants in each net plot produced tassel.

Days to 50% silking

Data was recorded as number of days from sowing to when 50% of the plants in each net plot started shedding pollen.

Days to 90% maturity stage

It was recorded as number of days from sowing to when 90% of the plants in each net plot formed black layer at the point where the kernel is attached to the cob.

Leaf area per plant

All available leaves of five plants per net plot were collected at 50% milking stage and leaf length and width was measured. The leaf area was determined bymultiplying leaf length and maximum leaf width adjusted by a correction factor of 0.75 as suggested by Francis *et al.* (1969).

Leaf area (LA) = Length x Maximum width of leaf (cm) x 0.75.

Leaf area index (LAI)

Itwas calculated as the ratio of total leaf area per five plants (cm^2) per area of land occupied by the plants (Diwaker and Oswalt, 1992).

$$\textbf{Leaf area index (LAI)} = \frac{\text{Leaf area } (cm^2)}{\text{Spacing of each plant}}$$

Plant height (cm)

Plant height of maize was measured in centimeter as the distances from ground level to the point where the tassel starts to branch for five plants randomly selected from the net plot. The mean was recorded as plant height.

Data Analysis

Data collected from the experimental field were analyzed using SAS computer software version 9.3 (SAS, 2002). Mean comparison of treatment was done using Tukey's test at 5% probability level of significance.

RESULTS AND DISCUSSIONS

The Analysis of variance showed that there was a significant main effect of weeding frequency and plant density ($P \leq 0.05$) on phenological and growth parameters of maize such as days to 50% tasseling and silking, days to 90% physiological maturity, leaf area, leaf area index and plant height. On the other hand; weed density, weed dry biomass weight and weed control efficiency were significantly affected by the main effects of weeding frequency and plant density as well as by their interaction ($P \leq 0.01$). Table 1

Weed Parameters

Weed flora in the experimental field

Twenty-one weed species belonging to twelve families infested the experimental plots (Table 2). Among these, fourteen, five and two species were broadleaved, grassy weeds, and sedge, respectively. The dominant weeds flora that infested maize during growing season were *Cyperusrotundus*, *Guizota scabra, Eleusine indica* and *Hyparrhenia hirta*. Among the weed species, maximum relative weed density was observed for broadleaved weeds (66.7 %) followed by grass weeds (23.8 %) and sedge (9.5 %). Species of *Poaceae and Asteraceae* are the most common, followed by *Cyperaceae*.

The possible reason for more weed species occurrence in the field could be related to poor weed management practices and favorable environmental factors. Similar result reported by Rezene *et al*. (1992) and Kasa *et al.* (2002).

Interaction effect of plant density and weeding frequency on weed density, weed dry biomass weight and weed control efficiency at harvest

Weed density

The highest (221.33 m^{-2}) weed density was obtained from 31,250 plant density ha^{-1} in combination with weedy check while no weed species were found for all plant

Table 1. Level of significance for weed parameters, pheonology and growth parameters of maize for weeding frequency, plant density and their interaction.

Source of variations	Weed density	weed dry biomass weight	weed control efficiency	Days to 50% tasseling	Days to 50% silking	Days to 90% maturity	Leaf area (cm^2)	Leaf area index	Plant height (cm)
Weeding Frequency (WF)	**	**	**	**	**	**	**	**	**
Plant Density (PD)	**	**	**	**	**	**	*	**	*
WF X PD	**	**	**	ns	ns	ns	ns	ns	ns

Where; ns, * and ** = non-significant, significantly different at 5%, and 1%, respectively.

Table 2. Weed flora found in the experimental field of Maize at AsARC Station, 2016.

Scientific name	Family	Category	Life cycle	Weed density(m^{-2})
Guizotia scabra(Vis)Chiov.	*Asteraceae*	Broadleaved	A	134.0
Cerastium fontanum Baumg.	*Caryophyllaceae*	Broadleaved	P	121.3
Galium aparinoides Forssk	*Rubiaceae*	Broadleaved	A	84.0
Physalis angulata L.	*Solanaceae*	Broadleaved	A	56.7
Ageratum conyzoies L.	*Asteraceae*	Broadleaved	A	48.0
Striga hermonthica(Delile)Benth	*Orobanchaceae*	Broadleaved	A	30.7
Scorpiurus muricatus L.	*Fabaceae*	Broadleaved	A	16.7
Polygonum nepalense Meisn.	*Polygonaceae*	Broadleaved	A	12.7
Bidens pilosa L.	*Asteraceae*	Broadleaved	A	5.3
*Bidens ferulifolia (*Jacq.*)* Sweet	*Asteraceae*	Broadleaved	A	2.0
Commelina benghalensis L.	*Commelinaceae*	-	A	2.0
Sonchus asper (L.) Hill	*Asteraceae*	Broadleaved	A	0.7
Mysotis arvensis (L.) Hill	*Boraginaceae*	Broadleaved	A	1.3
Euphorbia hirta L.	*Euphorbiaceae*	Broadleaved	A	0.7
Hyparrhenia hirta (L.) Stapf	*Poaceae*	Grass	P	130.7
Eleusine indica (L.) Gaertn.	*Poaceae*	Grass	A	128.7
Echinochloa crus-galli	*Poaceae*	Grass	A	13.3
Digitaria ischaemum (Schreb.)	*Poaceae*	Grass	P	8.7
Panicum dichotomiflorum	*Poaceae*	Grass	A	2.0
Cyperusrotundus L.	*Cyperaceae*	Sedge	P	150.7
Kyllinga brevifolia	*Cyperaceae*	Sedge	P	4.0

A = Annual, P = Perennial

densities combined with completely weed free plots. The mean weed density was decreased by about 83.8% at twice weeding as compared to weedy check plots. The reason for higher weed density at lowest plant density could be the wider intra and inter row spacing that might have provided adequate and more space for weeds to occupy than the other plant spacing. The highest weed density was obtained at a lowest plant density of 31,250 plants ha^{-1} in combination with the weedy check that was significantly higher than the combination of the highest plant density with weedy check (Table 3). This could be attributed to competitive advantage to crop; the later emerging weeds were suppressed by taller crop plants more under closer spacing thereby resulting in reduced weed density (Ashrafi *et al.,* 2009). In agreement with the current finding, Doğan *et al.* (2004) and Maqbool *et al.* (2006) stated that the number of weeds significantly affected by interaction effects of weed control and plant density of maize.

Weed dry biomass weight

Significant highest weed dry biomass weight (741g m^{-2}) which was significantly different from the rest of the treatments was obtained for 31,250 plants ha^{-1} in combination with the weedy check. The availability of more space for the weeds under wide spacing resulted in significantly higher density than the other spacing that might have resulted in higher weed dry biomass weight. In weedy check plots, increasing the plant density from 31,250 to 62,500 plants ha^{-1} caused a significant reduction (46.3 %) in the weed dry biomass weight.At all level of plant density; twice weeding was able to

Table 3. Interaction effect of Weeding Frequency and Plant Densities on weed density, weed dry biomass weight and weed control efficiency at Assosa District, 2016.

Plant Densities per hectare	Weeding Frequency	Weed density (m^{-2})	Weed dry biomass yield	Weed control efficiency
31,250 plants ha^{-1}	Weedy Check	221.3^{a}	741.0^{a}	0.0^{h}
	Once weeding	188.7^{abc}	354.0^{bcd}	52.2^{de}
	Twice weeding	99.3^{ef}	110.0^{f}	79.7^{bc}
	Completely weeding	0.0^{g}	0.0^{g}	100.0^{a}
44,444 plants ha^{-1}	Weedy Check	198.7^{ab}	357.3^{bd}	0.0^{h}
	Once weeding	134.7^{cdef}	272.0^{de}	23.3^{fg}
	Twice weeding	118.0^{def}	86.7^{fg}	75.7^{bc}
	Completely weeding	0.0^{g}	0.0^{g}	100.0^{a}
53,333 plants ha^{-1}	Weedy Check	186.0^{abc}	446.7^{b}	0.0^{h}
	Once weeding	144.7^{bcde}	255.3^{e}	42.9^{ef}
	Twice weeding	113.3^{def}	29.3^{fg}	93.4^{ab}
	Completely weeding	0.0^{g}	0.0^{g}	100.0^{a}
62,500 plants ha^{-1}	Weedy Check	138.0^{bcde}	342.7^{cde}	0.0^{h}
	Once weeding	175.3^{abcd}	377.3^{bc}	22.9^{g}
	Twice weeding	74.0^{f}	92.4^{fg}	71.7^{cd}
	Completely weeding	0.0^{g}	0.0^{g}	100.0^{a}
LSD (5%)		62.6	97.2	19.7
CV (%)		18.37	14.75	12

Means for each treatment in a column followed by the same letter are not significantly different from each other at (α= 0.05) according to Tukey test

significantly reduce weed dry biomass weight compared to weedy check. This indicates that twice weeding is sufficient enough to significantly reduce weed dry biomass weight and hence avoid any competition for resources. In general, high plant density reduced weed dry biomass weight significantly compared to the low plant density suggesting that high density plant provided good smothering effects on growth and development of weeds due to less availability of space as well as shading (Abouziena et al., 2008). Similarly, Teymuri *et al.* (2011), Bakhtiar *et al.* (2009) and Chikoye et al. (2004)reported that decline of weeds dry biomass weight due to increment of maize plant density combined with weedy check.

Weed control efficiency

There was a significant interaction effect of weeding frequency and plant density on weed control efficiency (Table 3). The highest weed control efficiency was recorded for completely weeding plot, followed by twice weeding while the lowest weed control efficiency recorded at weedy check at all level of plant density.Twice hand weeding was more effective in reducing the density and dry weights of weeds as compared to weedy check next to completely weed free plots (Table 3). The higher weed control efficiency could be attributed to the lower weed density and weed dry weight in these treatments. The significantly lower weed control efficiency under the influence of weeding frequency (weedy check and once weeding) for all plant densities compared to twice and complete weeding could be due to the lack of proper weed control practices to reduce infestation of weeds. The increased weeding frequency might benefit the crop better than the weeds and consequently the crop would suppress the weed growth and result in higher weed control efficiency (Mashingaidzeet al., 2009).

Main effect of weeding frequency and plant densities on Phenological and growth parameters of maize

Effect of weeding frequency

Days to 50% tasseling and silking

Weeding frequency increased the duration of tasseling time of maize. Changing weeding practice from weedy check to twice weeding resulted in reducing days to 50% tasseling by 1.5 days (Table 4). However, completely weeding didn't differently affected days to 50% tasseling from twice weeding. This result was in agreement with the finding of Evans *et al*. (2003) and Muhammad *et al*. (2012) who mentioned that tasseling delayed at higher weed densities. Infestation of weeds significantly ($P\leq 0.05$) delayed the silking in maize plants and this delay varied from 0.59 -1.59 days in weedy check as compared to other weeding practices. The highest days to silking (92.42 days) was recorded with weedy check and the lowest days to 50% silking was at twice weeding (91 days). However, days to silking didn't significantly varied between weedy check and once weeded as well as

Table 4. Main effect of weeding frequency and plant densities on Phenological and growth parameters of maize at Assosa District, 2016

Treatments	Days to 50% tasseling	Days to 50% silking	Days to 90% maturity	Leaf area (cm^2)	Leaf area index	Plant height (cm)
Weeding frequency						
Weedy check	84.8^{a}	92.4^{a}	162.8^{a}	4679^{b}	2.25^{b}	204^{b}
Once weeding	84.1^{ab}	91.8^{ab}	162.0^{ab}	5575^{a}	2.64^{a}	222^{a}
Twice weeding	83.0^{c}	90.8^{b}	160.8^{c}	5628^{a}	2.68^{a}	224^{a}
Completely weeding	83.2^{bc}	90.9^{b}	161.2^{bc}	5593^{a}	2.65^{a}	224^{a}
LSD (5%)	0.92	1.02	1.04	366	0.172	7.46
Plant density (ha^{-1})						
31,250 plants ha^{-1}	83.2^{b}	90.8^{b}	161.0^{b}	5640^{a}	1.78^{d}	213^{b}
44,444 plants ha^{-1}	83.3^{b}	90.9^{b}	161.3^{b}	5469^{ab}	2.43^{c}	217^{ab}
53,333 plants ha^{-1}	83.8^{b}	91.7^{ab}	161.6^{b}	5248^{b}	2.81^{b}	220^{ba}
62,500 plants ha^{-1}	84.8^{a}	92.6^{a}	162.8^{a}	5118^{b}	3.20^{a}	224^{a}
LSD (5%)	0.92	1.02	1.04	366	0.17	7.46
CV (%)	1.34	1.33	0.76	8.26	8.17	4.14

Means within the same factor and column followed by the same letter are not significantly different at P = 0.05

between twice and completely weeding.

The shading of crop plants with weeds might have reduced sunlight penetration thus prolonging the vegetative growth resulting in delayed days to silking (Mengesha *et al.,* 2015).

Days to Physiological maturity

Maturity period of maize has a direct relationship with days to 50% tasseling and days to 50% silking. Factors that retard days to tasseling and silking may also retard time of maturity. Significantly longer days to physiological maturity was recorded for weedy check, followed by once weeding while significant shorter days to physiological maturity was recorded for the twice weeding and complete weeding (Table 4). The days to maturity for twice weeding and complete weeding were significantly earlier than the other two weeding frequencies (weedy check and once weeding) while there was not significant difference existed between weed free and twice weeding. This indicates that the number of days to physiological maturity was significantly delayed due to weed infestation throughout the crop growth over other treatments. Evans *et al*. (2003) and Muhammad*et al*. (2012) reported the same result.

Plant height

Plant height is an important growth parameter directly linked with the productive potential of plants in terms of fodder and grain yield (Saeed *et al*., 2001).Weeding frequency significantly reducing plant height of maize. The mean plant height was increased by 8.9, 9.8 and 9.9 % for the plots weeded once, twice and complete plots, respectively as compared to the plants from the control plots. Plants, which were kept weed-free throughout the season, were significantly taller (224 cm) than the plants in weedy check plots as well as once and twice weeding plots. The reduction in plant height due to weeds may be attributed to several factors, i.e. competition between maize and weeds for water and nutrients, especially nitrogen and allelopathic effects of weed (Soliman and Gharib, 2011).This result was in agreement with Adenawoola *et al.* (2005), Abouziena *et al.* (2007) and Ahmed *et al*. (2008) who obtained significant increase in various growth parameters of maize in practices with more weeding frequency.

Leaf area

Leaf area influences interception and utilization of solar radiation of maize crop canopies and, consequently, maize dry matter accumulation and grain yield (Boote *et al.,* 1996). Significantly higher leaf area was recorded for the plants from once, twice and completely weeding plots as compared to the lowest leaf area (4679 cm^2) was recorded for the control plot implying a positive response of leaf area to weeding frequency. Increasing weeding frequency from no weeding to once and twice weeding increased the leaf area by 19 and 20%, respectively (Table 4). However, the effect of weeding frequency for complete, twice and once weeding on leaf area didn’t differ significantly. The increase in the maize leaf area as affected by weed control resulted from the increase in number of green leaves per plant (El-Saeed, 2012). The result was agreed with Bakhtiar*et al*. (2009) and Cathcart and Swanton (2004) reported that under extensive weed control in maize fields, leaf area increases under weed-free conditions.

Leaf area index

Leaf area index is major factor determining photosynthesis and dry matter accumulation (Moosavi *et al.*, 2012). Significantly highest leaf rea index (2.68) was recorded from twice weeding while the lowest (2.25) was recorded from the control plot (Table 4). Once, twice and complete weeding didn't significantly differ in influencing leaf area index. However, twice weeding plot resulted in 18.8 % more leaf area index over no weeding. Increase in leaf rea index at weed free plots explains that increasing weeding frequency increases leaf area index on account of more area occupied by green canopy of plants per unit area. The reduced competition and increased availability of resources like nutrients, soil moisture and light paved way for higher leaf area index (El Naim and Ahmed, 2010). The result of this study was in good agreement with Mahmoodi and Rahimi (2009), Bakhtiar *et al*. (2009), Karimmojeni *et al.* (2010) and Soliman and Gharib (2011) where that increasing weed densitysignificantly decreased leaf area index of maize.

Effect of Plant Density

Days to 50% tasseling and silking

Increasing plant population tended to increase days to 50% tasseling and silking. Significantly the longest days to tasseling (85) was observed for the highest plant density of 62,500 plants ha^{-1} while the shortest days (83) to tasseling was observed at lowest plant density of 31,250 plants ha^{-1}. Days to 50% tasseling, however, didn't significantly differ between the other plant densities. Similarly, the highest plant density of 62,500 plants ha^{-1} delayed days to silking by 1.66 days compared with the lowest plant density 31,250 plants ha^{-1} (Table 4). Delayed tasseling and silking 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 (Muhammad *et al.*, 2012). Furthermore, this might be due to the fact that the highest plant densities, enhanced competition between crop plants for different growth resources especially light that might have slowed the rate of phenological development that ultimately delayed tasseling. The result was consistent with the finding of Shafi *et al.* (2012) and Bhatt (2012) indicted that delayed tasseling and silking was observed at more dense population as compared to less dense population.

Days to 50% maturity

Increasing plant density showed similar trend with days to 50% silking and days to 50% tasseling, the days to maturity was increased. But there was no significant difference between plant densities of 31,250 and 53,333 plants ha^{-1}. Significant difference in maturity was observed between the highest plant density and lowest plant density (Table 4). Maize plants at low planting density reached maturity earlier, and plants of high planting density were late. This may be due to there was an intra-specific competition effect at higher maize densities; thus, the plants transferred the resources to vegetative growth causing delay in the reproductive growth which eventually increased the number of days to maturity (Zahid *et al.*, 2013). Delay in maturity due to high plant densities has also been reported by Imran *et al.* (2015) and Bhat (2012).

Plant height

The plant density increased from 31, 250 plants ha^{-1} to 62,500 plants ha^{-1}, plant height was also tended to increase. The highest plant height (224 cm) was recorded at the highest plant density of 62,500 plants ha^{-1} while the lowest plant height (213 cm) was recorded at the lowest plant density of 31, 250 plants ha^{-1} (Table 4). However, plant height recorded at a plant population of 62,500, 53,333 and 44,444 plants ha^{-1} were all at par. This indicated that at highest plant density the competition for light resulted in tall plants as compared to the lowest plant density. This results in agreed to Ibeawuchi *et al.* (2008), Babaji *et al.* (2012) and Seyyed *et al*. (2012) who reported that the higher competition for light might have been the reason for production of taller plants at the highest density.

Leaf area

Significantly the highest leaf area (5640 cm^2) was recorded at the lowest plant density of 31,250 plants ha^{-1} and the lowest leaf area (5118 cm^2) was recorded at the highest plant density of 62,500 plants ha^{-1}. Leaf area of plants from the plant density of 31,250 and 44,444 plants ha^{-1} didn't differ significantly. Likewise leaf area of plant from the plant density of 44,444, 53,333 and 62,500 plants ha^{-1} also didn't differ significantly (Table 4). The reduced leaf area with higher plant density might be due to high competition for assimilates at higher plant density resulting in less average leaf area per plant. Increasing plant density reduces leaf area because of the accelerated leaf senescence, increased shading of leaves, and reduced the net assimilation of individual plants (El-Saeed, 2012). The result was in agreement with Imran *et al.* (2015) and Amona (2014) stated that lower plant population got more nutrients and water compared to higher population and in turn increased leaf area.

Leaf area index (LAI)

Leaf area index increased with increase in plant density. Significantly highest LAI of 3.2 was recorded at the highest plant population of 62,500 plants ha^{-1}while the lowest leaf area index (1.78) was obtained with the lowest population of 31,250 plants ha^{-1} (Table 4). Valadabadi and Farahani (2010) reported that leaf area index is influenced by genotype, plant population, climate and soil fertility. The highest physiological growth indices were achieved under high plant density because photosynthesis increases by development of leaf area (Abuzar *et al.,* 2011). The result was consistent with the finding of Mohammad *et al.* (2012) and Dinh *et al.* (2015) who stated that increasing plant density increased the leaf area index significantly and linearly.

CONCLUSION

In this study, combination of increased plant density with weeding frequencies reduced weed competition thus decrease weed density and weed dry biomass weight, increased phenology and growth parameters of maize. Hence, it can be concluded that use of twice hand weeding and a plant density of 53,333 plants ha^{-1} (75cm x 25 cm) were profitable for variety BH-546 production and recommended for the area.

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