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EFFECT OF MAIZE PLANTING DENSITIES ON VARIOUS GROWTH PARAMETERS OF BARNYARD GRASS

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ABSTRACT

To investigate the effect of planting densities (i.e. 12, 9, 6 and 3 plants m^{-2}) of maize cv. Azam on suppression of barnyard grass, a field trial was undertaken at New Developmental Research Farm, the University of Agriculture, Peshawar, Pakistan from June-October 2006. The trial was laid out in a randomized complete block design with four replications. Growth parameters such as plant height, leaf area, and specific leaf area $plant^{-1}$ and shoot dry biomass were recorded both for maize and barnyard grass while grains cob^{-1}, 1000 grains mass and grain yield was recorded only for maize. Different planting densities of maize had showed significant effects upon various growth parameters of barnyard grass and maize crop. Overall, the higher planting densities have shown better suppression of barnyard grass growth but at the highest planting density (12 maize plants m^{-2}), the crop suffered its yield possibly due to intra-specific competition between the crop plants. The moderately high density (9 maize plants m^{-2}) produced best results in this study. Therefore, it can be recommended that 9 maize plants m^{-2} may be planted for better suppression of barnyard grass and harvesting higher yields of maize.

Key-words: Plant densities, growth parameters, barnyard grass, maize

INTRODUCTION

Maize (*Zea mays* L.) (Family Poaceae) cross pollinated annual plant, is the third most important cereal crop of Pakistan after wheat and rice (Chaudhry, 1994). Maize bears cylindrical stem consisting of several nodes and internodes. Its broader leaves are arranged at each node. In 2008-2009, in Pakistan, maize was cultivated on 1052.1 thousands hectares area which produced 3593.0 tons grains with an average yield of 1419 kg ha^{-1}, however, in Khyber Pakhtunkhwa province, it was sown on 509.5 thousand hectares and produced 957.9 tons grains with an average yield of 1880 kg ha^{-1} (Anonymous, 2009). Maize is a multipurpose crop (e.g. used as human food, animal's and poultry feed, and in industrial products) (Bibi *et al*., 2010).

There are several production constraints of maize in Pakistan (*viz*. unavailability of improved and high yielding varieties seed, high cost of agricultural practices and inputs, various pathogens and insects etc.), but weeds infestation is considered to be one of the important constraints to be focused on as weeds compete with the crop for nutrients, moisture and light and significantly reduce its yield and market value. Weeds are reported to reduce maize yield from 20-40% (Ashique *et al*., 1997). Several weeds infest maize crop in Peshawar valley; including field bindweed (*Convolvulus arvensis*), bermuda grass (*Cynodon dactylon*), *Cyperus rotundus*, false amaranth (*Digera muricata*), *Digitaria sanguinalis*, *Echinochloa colonum*, Johnson grass (*Sorghum halepense*), puncture-wine (*Tribulus terrestris*) and barnyard grass [*Echinochloa crus-galli*) etc. (Chaudhry, 1994; Hassan *et al*., 2010).

Barnyard grass, an erect summer annual grass with small cylindrical tufted stem and fibrous root system often growing from lower nodes of the plant up to 1.5 m height. It has lanceolate leaf (40 cm long and 15 mm in width), deep green and with a visible midrib. Inflorescence of the grass bears nearly 15 spikelets in a lance-shape arrangement and is mostly straight. Its spikelet color is green and with purple complexion. Its grains turn pale brown at maturity. Barnyard grass is very abundant in maize (Ullah *et al*., 2008), significantly reducing the yield of the crop in Peshawar valley (Ullah *et al*., 2008). This is because this weed is a large seed producer, continuously enriching its soil seed bank and highly competitive (Holm *et al*., 1991; Koo *et al*., 2000) particularly during early growth of maize. Barnyard grass has also been noted inhibitory to seed germination and radical growth of maize seedlings due to its allelopathic nature (Hamayun *et al*., 2005).

Although various weed control measures (e.g. hand weeding, mechanical weeding and the use of herbicides) are effective against barnyard grass in maize, but most of these control measures possess limitations. For instance, hand and mechanical weeding is not always feasible during the early growth periods of the crop due to monsoon rains or labor shortage (Chaudhry, 1994) and herbicidal control needs to be done repeatedly due to re-emergence of the weed from the soil seed bank which may cause herbicide resistance due to repeated use of the same mode of action herbicides. In addition, herbicides may also pollute the environment. Thus, additional control measures may help reduce losses by barnyard grass to the maize crop. One such approach could be planting maize at higher densities which may increase its competitive ability upon the weed. Higher planting densities have been used to suppress weeds and to increase yield of the crop (Shapiro & Wortmann, 2006). Kumar and Walia (2003) demonstrated highly productive maize crop grown at 8-9 plants m^{-2} because of better competition of the dense and greater canopy closure upon weeds (Dalley *et al*., 2006). So far little attention has been paid to the use of higher plant densities of the crop to manage barnyard grass in Pakistan, which may help minimize yield losses to the crop. Therefore, a study was planned to investigate the effect of different maize planting densities on the suppression of the weed and on the yield of the crop.

MATERIALS AND METHODS

Plant materials and experimental design: A field trial was conducted at Malakandher Research Farm, Khyber Pakhtunkhwa, Agricultural University Peshawar- Pakistan during mid June, 2006 in order to investigate the effect of four planting densities (very high= 12, high= 9, medium= 6 and low= 3 plants m^{-2}) of maize cv. Azam on the suppression of barnyard grass (BYG) and on the maize production. The experimental site (34°1'14"N 71°28' 53"E) is having a sub-tropical climate, clay soil, having 7.3 pH, and uniformly infested with barnyard grass (BYG).

The experiment was laid out using a randomized complete block design with four replicates of each treatment. Prior to sowing, the field was irrigated and ploughed twice at field capacity using a cultivator and all weeds were destroyed followed by planking to break the clods to prepare fine seed beds for seed germination. An area measuring 6 x 4 m^2 was assigned to each treatment. During seed bed preparation, nitrogen as Urea and phosphorus as Single Super Phosphate was applied at @120 and 50 kg ha^{-1}, respectively to supplement the crop growth. Seed of cv. Azam was sown at higher seed rate to achieve sufficient seedlings. In all experimental plots, the seeds were sown in five rows 74 cm apart from each other using drill method. After seed germination (*ca*. 6 days after sowing), all extra seedlings were thinned and the required maize densities were maintained in each treatment. The seed of barnyardgrass (BYG) (previously collected from the same area) was mixed with saw dust to facilitate its evenness and hand broadcasted inside the experimental plots. After seed germination of barnyard grass (BYG) (*ca*. 4-5 days), a fixed density (15 plants m^{-2}) in all treatments was maintained while all its extra plants and other weeds were uprooted and removed. A weedy check (containing 15 barnyard grass (BYG) plants m^{-2}) was maintained with each treatment for comparison. The trial field was watered using irrigation canal water when required. The trial was thoroughly examined on weekly basis and if any kind of self-emerged weeds were found, uprooted and removed. The experiment was run for 86 days.

Measurement of growth traits and statistical analysis: For maize and barnyard grass (BYG), data were recorded on plant height (cm), leaf area (LA) (cm^2) and specific leaf area (SLA) per plant at 50% silking of maize. Shoot dry biomass (SDM) (kg ha^{-1}) was recorded both for maize and BYG at crop maturity. Grains cob^{-1}, 1000 grain mass and grain yield (kg ha^{-1}) was recorded only for maize. To record plant height, 10 mature plants of both maize and barnyard grass (BYG) (after 86 days of emergence) were randomly selected inside each plot and measured from the ground level to the top using a wooden measurement rod. Leaf area of 10 randomly selected plants of maize and barnyard grass (BYG) from each plot was measured using Leaf Area Meter (LI- COR 3100 model USA) and SLA was derived from the total LA and total leaf dry mass (LA $plant^{-1}$/LDM $plant^{-1}$). Leaf dry mass was recorded by cutting all leaves from 10 randomly selected plants of maize and barnyard grass (BYG) in each plot using a scissor, placed separately in paper bags, dried in an oven at 70 ± 2 ^{o}C for 48 h and weighed. Grains cob^{-1} was visually counted by randomly selecting 10 plants of maize in each plot. The 1000 grains mass was measured with an electronic balance. To record SDM, a quadrate (0.25 m^2) was four times randomly thrown in each plot and all plants of maize and barnyard grass (BYG) inside the quadrate were harvested at soil level using a cutter. Their plants were separated, placed in marked paper bags, dried in an oven at 70 ± 2 ^{o}C for 48 hrs and weighed. To record grain yield, all cobs were removed from the dried maize plants (harvested from 0.25 m^2 area), threshed, placed in plastic bags, and weighed and then were converted into kg ha^{-1}.

Analysis of variance (ANOVA) using Minitab-15 analysis package was separately run on the data of all growth parameters of maize and BYG to rank the four maize densities used against suppression of BYG. In addition, least significant difference (LSD) test was performed to identify significant differences among the means of different treatments (Steel & Torrie, 1980).

RESULTS AND DISCUSSION

Plant height: Analysis of the data indicated significant effect of maize densities upon the plant height of BYG and maize (p= 0.000). Barnyard grass produced shortest (30.0 and 38.5 cm) plants while in competition with 12 and 9 maize plants m^{-2}, respectively and were statistically at par (Table 1). A decreasing trend of maize plant height was observed with decreasing plant density. Tallest maize plants (174.6 cm) were recorded @ 12 maize plants m^{-2} followed by 9 maize plants m^{-2} (Table 1). Tallest BYG plants (107.5 cm) were found in the weedy check (Table 1). Our results are in agreement with Singh and Singh (2006) who found an increasing trend of plant height with increasing density of maize. The height increase at higher densities may have occurred due to the intra-specific competition for light between the maize plants as has been observed by Sekimura *et al*. (2000). One further reason could be the inherent good plant height of cv. Azam (Hassan *et al*., 2010) which may have suppressed BYG height.

Leaf area: Analysis of the data showed significant influence of maize densities on the LA of both BYG and maize (p= 0.000). The least LA of BYG was observed at 12 plant m^{-2} followed by 9 and 6 plants m^{-2} while its largest LA was noted in its pure culture referred to as weedy check (Table 2). Maize grown at 9 plants m^{-2} had significantly greater LA (244.2 cm^2) than 12 plants m^{-2} (210.2 cm^2) (Table 2). The smaller leaf area at 12 plants m^{-2} was possibly due to the intra-specific competition between the maize plants for growth resources as has been reported by Murphy *et al*. (1996) and the smaller LA at 3 maize plants m^{-2} was probably due to the severe competition from BYG plants. These results can be compared with Bosnic and Swanton (1997) who noted 23% decrease of LA in BYG by maize grown at higher densities. Leaf area is one of the important growth traits as it influences capture of solar radiation which is important for rapid growth of plants (Valentinuz & Tollenaar, 2006). Thus, plant density of maize per unit area may affect the leaf size and its overall canopy closure which may aid in the competitive ability of maize against BYG.

Specific leaf area: Specific leaf area is vital in leaf and plant functioning, and regulates strategy of resource acquisition and plants growth (Li *et al*., 2005). Results showed significant effect of maize densities on BYG and maize SLA accumulation (p= 0.002 and 0.029, respectively). Barnyard grass gained lowest SLA at 12 and 9 maize plants m^{-2} (Table 2). As density of the crop decreased, SLA of the weed increased. The results also revealed decreased SLA for maize with its decreasing density possibly due to poor competition with BYG, however, the thickest and statistically similar SLA of maize was found at 12 and 9 plants m^{-2} probably due to better competition of the crop plants with the weed plants (Table 2). These findings are in accordance with Singh and Singh (2006) and Page *et al*. (2010).

Grains cob^{-1}: Analysis had confirmed significant effect of maize densities on grains cob^{-1} while in competition with BYG (p= 0.001). Maximum grains cob^{-1} (222.1) were set at density of 9 plants m^{-2} while minimum (87.9) at maximum density of 3 plants m^{-2} (Table 3). Although, the BYG growth significantly suffered at 12 maize plants m^{-2}, but due to the intra-specific competition for light quantity between the maize plants, it could not achieve greater grains cob^{-1}. Gracietti *et al*. (2002) and Shapiro and Wortmann (2006) have suggested that maize yield can be boosted with increased planting density however; they also reported that excessive density can also cause yield loss due to intra-specific competition. This suggests that moderately high densities may be useful to minimize intra-specific competition between the crop plants and wisely suppress BYG to achieve higher grain production as has been reported by Matta *et al*. (1990).

1000 grains mass: Maize grown at different densities while in competition with BYG showed significantly different gain of 1000 grains mass (p= 0.000). Maize grown at 9 plants m^{-2} gave the heaviest 1000 grains (141.8 g) while at 12 and 6 plants m^{-2} density it gave 132.0 and 114.5 g 1000^{-1} grains, respectively (Table 3). Porter *et al*. (1997) and Kumar and Walia (2003) noted lower growth of weeds in maize grown at 8-9 plants m^{-2}. Maize achieved lightest mass 1000^{-1} grains at 3 plants m^{-2} (Table 3). As has been discussed above, reduction of maize growth may be attributable to the intra-specific competition between its plants at its highest planting density, thus its lower 1000 grains mass at 12 plants m^{-2} may also have occurred due to this factor. Conversely, Bavec and Bavec (2002) have demonstrated 13.5 plants of maize m^{-2} to be effective to suppress weeds and to promote 1000 grains mass.

Grain yield: Maize densities had significantly affected its grain yield while competing with BYG (p= 0.000). The maximum and statistically at par grain yield of maize (i.e. 2732 and 2696.0 kg ha^{-1}) was noted in plots sown with 12 and 9 plants m^{-2}, respectively followed by the plots containing 6 plants m^{-2} (Table 3). The lowest grain yield (1657.1 kg ha^{-1}) was recorded at 3 plants m^{-2} (Table 3). Better grain yield production at the higher densities levels of maize looks to be linked with the better suppression of BYG by maize and the crop was able to efficiently utilize growth resources due to reduced competition from the weed. These results are in line with Widdicombe and Thelen (2002) and Accaires and Zuluaga (2006) who found dense maize crop effective against weeds suppression and for promoting grain yield. Other studies have also exhibited similar results (Kumar & Walia, 2003; Ullah *et al*., 2008).

Table 1. Plant height of barnyard grass and maize as affected by different planting densities of maize.

Maize density m^{-2}	Plant height (cm)	
	Maize	Barnyard grass
12	174.6a	30.0d
9	153.5b	38.5d
6	123.7c	69.8c
3	108.8d	87.3b
Weedy check	-	107.5a

LSD (at p<0.05) for maize plant height = 14.2 and for BYG plant height = 7.8

Table 2. Leaf area and specific leaf area $plant^{-1}$ of maize and barnyard grass as affected by different planting densities of maize.

Maize density m^{-2}	Leaf area (cm^2)		Specific leaf area (m^2 / kg)	
	Maize	Barnyard grass	Maize	Barnyard grass
12	210.2b	33.9e	5.2ab	3.4de
9	244.2a	45.3d	5.5a	3.2d
6	133.8c	80.4c	4.4c	4.6bc
3	91.1d	119.3b	3.8cd	4.8b
Weedy check	-	168.7a	-	5.9a

LSD (at p<0.05) for maize leaf area = 8.1 and for BYG leaf area = 7.2
LSD (at p<0.05) for maize specific leaf area = 0.9 and for BYG specific leaf area = 0.7

Table 3. Grains per cob and 1000 grains mass of maize as affected by different planting densities of maize and barnyard grass.

Maize density m^{-2}	Grains cob^{-1}	1000 grains mass (g)	Total grain yield (kg ha^{-1})
12	128.9c	132.0b	2796.0ab
9	222.1a	168.8a	2732.0a
6	143.6b	114.5c	2156.7c
3	87.9d	74.8d	1657.1d
Weedy check	-	-	-

LSD (at p<0.05) for grains cob^{-1} = 16.3, for 1000 grains mass = 14.8 and for total grain yield = 51.1

Table 4. Shoot dry biomass of maize and barnyard grass as affected by different planting densities of maize.

Maize density m^{-2}	Shoot dry biomass (kg ha^{-1})	
	Maize	Barnyard grass
12	7614.0a	2133.5e
9	7532.9b	2370.1d
6	6687.4c	2621.8c
3	5676.2d	3194.7b
Weedy check	-	3202.0a

LSD (at p<0.05) for maize shoot dry biomass = 132.2 and for barnyard shoot dry biomass = 87.1

Shoot dry biomass: Different planting densities of maize exhibited significant effect on the SDB production of BYG (p= 0.001) and maize (p= 0.000). The results revealed a decreasing trend of SDB in BYG with increasing maize density. The least SDB (2133.5 kg ha^{-1}) was yielded at 12 plants m^{-2} followed by 9 plants m^{-2} (Table 4) while BYG had achieved the greatest SDB (3202.0 kg ha^{-1}) in the absence of maize competition (control plots) followed by plots grown at 3 and 6 plants m^{-2} maize plants (Table 4). As has been demonstrated above, that the production of greater SDB may be due to the reduced competition from the BYG plants due to greater competition from maize plants at the higher densities and in such situations the weed plants were likely not able to utilize the growth resources efficiently and grow rapidly. As a result, the maize plants achieved greater SDB. These results are supported by Accaires and Zuluaga (2006), Dalley *et al*. (2006) and Travlos *et al*. (2011), all of them could found less SDB of weeds at denser maize stands and consequently increased shoot biomass production.

Conclusions

The moderately higher planting density of maize (9 plants m^{-2}) proved to be highly suppressive against the growth of BYG and also useful to enhance maize production, however, the very high maize density (12 plants m^{-2}) was not useful for maize yield increase although at this planting density, the BYG growth was highly suppressed. Thus, it can be concluded that 9 plants of maize m^{-2} may be suitable to suppress BYG as well as achieve greater maize yield.

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