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GROWTH AND YIELD OF MAIZE (*ZEA MAYS* L.) AS AFFECTED BY ROW SPACING AND WEED COMPETITION DURATIONS

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Abstract

A field experiment was conducted for two consecutive years (2003 and 2004) to study the effect of row spacing (75, 65 and 55cm) and different weed competition durations (0, 15,30,45,60 days after emergence and throughout the growth period) on weeds density and biomass and growth and yield of maize. Reducing row spacing significantly suppressed the weed density and biomass. The maximum reductions in weed density (9 %) and dry weight (34%) were recorded in 55 cm row spacing as compared with 75 cm row spacing. However, the effect of row spacing on maize grain yield was non significant in both years. Weed population and biomass in all weed-crop competition durations was significantly higher than weed free crop and resulted in a considerable reduction in crop growth and yield. The maximum reduction in crop growth rate (38%), leaf area index (44%) and grain yield (51%) were recorded in full season weed-crop competition as compared with weed free crop. The row spacing of 55 cm in maize was effective in suppressing weeds and the maximum weed density and biomass at 30 days after emergence indicate the need of early weeding in maize.

Introduction

Although maize (*Zea mays* L.) plant is vigorous and tall growing in nature, yet it is very sensitive to weed competition at early stages of growth (Mabasa *et al*, 1996; Kumar and Sundari, 2002). The commonly reported losses due to weeds in maize are greater than 30% (Rehman, 1985). In Pakistan, on an average 45% reduction in maize yield due to weeds infestation has been reported (Rashid and Shahida, 1987). Uncontrolled weeds may reduce maize yield as much as 90% (Madrid and Vega, 1976). Understanding of the ecological relationships in weed-crop competition are thus of significant importance in order to develop an effective crop management technology and to prevent the huge losses due to weeds.

Crop plants and weeds interfere with growth activities of each other to a varying degree and compete for moisture, mineral nutrients, and light and hinder harvest operations (Ratta *et al.*, 1991). It is not enough to simply say that weed-competition reduce the crop yield, but need to explore the critical period in weed-crop competition which may seriously can limit crop yield and the crop should be kept weed free during this period to alleviate the harmful effects caused by weeds. This will help in the economic utilization of the applied inputs. After the information is available, one has to resort the various methods of weed control that are feasible and economical under prevailing conditions.

Among agronomic practices, which affect the yield, inter row spacing has a special significance since it is ultimately related with plant population, root development, plant growth and fruiting (Davi *et al.*, 1995). Generally, the most appropriate spacing is one, which enables the plants to make the best use of the conditions at their disposal (Lawson and Topham, 1985; Malik *et al*., 1993). Too close spacing interferes with normal plants development and increase competition resulting in yield reduction, while too wide spacing may result in excessive vegetative growth of plant and abundant weed population due to more feeding area available. Therefore, use of optimum plant population per unit area without exceeding the economic threshold can increase the competitive ability of the crop plants in weed-infested field (Murphy *et al.,* 1996). However, growing crops in narrower row spacing can reduce weed growth although the degree of reduction will depend on the crop (Alford *et al*., 2004). Weed growth is most likely reduced because of increased light interception by the crop canopy in narrow rows early in the growing season. While reducing weed growth, yields may be increased in sugar beet or not affected in maize and dry bean (Alford *et al*., 2004) but research in northern areas of the United States has shown yield increases of up to 9.9% by growing maize in rows narrower than 76 cm (Paszkiewicz, 1998; and Roth, 1997). In addition to improving crop yields, reduced row spacing can also provide the crop with a competitive advantage over weeds. In another study weed biomass was reduced 28% by reducing row spacing to 56 cm and by 16 to 29% in 38 cm rows (Begna *et al*., 2001, Stewart, 2001 and Tharp and Kells, 2001). However, research in Minnesota found that reducing row spacing had no significant impact on weed biomass (Johnson *et al.*, 1998). One theory for the reduced weed growth in narrow rows is quicker row closure, which reduces the light penetration to the weeds emerging below the crop canopy. Thus the objective of the present study was to study the effects of row spacing/plant population and weed competition durations on weed density and biomass and growth and grain yield of maize.

Materials and Methods

The experiment was conducted at the Agronomic Research Area, University of Agriculture, Faisalabad (Pakistan) during the 2003 and 2004 growing seasons. The soil type was sandy clay loam with EC_e 1.1 m mhos cm^{-1}, pH 7.8 and organic matter 1.16%. Total available nitrogen, phosphorous and potassium were 0.049%, 7.29 and 190 mg kg^{-1}, respectively. The experimental design was a randomized complete block with split plot arrangement. Each treatment was replicated four times. Three inter-row spacing randomized in main plots were: 75,65 and 55 cm. While sub-plot treatments were six weed-infested periods in which, weeds were allowed to grow for 0,15,30,45,60 days after emergence (DAE) and throughout the growth period of maize (weedy check). After prescribed weed competition duration plots were kept free of weeds until harvest. Each sub plot consisted of six rows, measuring 7 m long. High natural weed populations of *Trianthema portulacastrum*, *Cyperus rotundus* and *Echinochloa colonum* were observed in the experimental area during both years.

Maize hybrid "Dahklab 919' was planted on 2^{nd} August 2003 and 6^{th} August 2004, respectively. The experiment was hand planted intending to achieve a desirable plant population ha^{-1}. Two seeds were dropped per hill to assure the desired stand in each treatment. The space between the two adjacent hills with in each row was 20cm for each of the row width. According to local soil test recommendations a basal dose of fertilizers @ 150 kg N plus 100 kg P_2O_5 ha^{-1} and 100 kg K_2O was applied in the respective plots in the form of urea, diammonium phosphate and potassium sulphate, respectively. Whole of the quantity of phosphorous, potash and half nitrogen was drilled at sowing and remaining half nitrogen was top dressed at the time of 2^{nd} irrigation.

Plant population was adjusted by thinning the crop when the plants had developed four fully expanded leaves. Carbofuran (Furadan 3-G) @ 0.6 kg a.i ha^{-1} was applied to protect the crop from maize borer and shoot fly. Total of seven irrigations (7.5 cm depth of each irrigation), were applied through flooding and when needed at different plant developmental stages, till the physiological maturity of crop

After prescribed weed competition duration a quadrate measuring 1m x 1m was randomly placed at two sites in the respective plots to record weed density; weeds were counted and then cut from ground surface for recording fresh and dry weight. After measuring the fresh weight, weed samples were oven dried at 70°C to a constant weight and dry weight was recorded. Leaf area of five randomly selected plants from each plot was measured at 75 DAE using a portable leaf area meter Model IL 3100, Nebraska, and then the leaf area index (LAI) was calculated summing the leaf area of the five plants samples and dividing it by the theoretical ground spaced occupied for them. Crop Growth Rate (CGR) was calculated by using the formula as proposed by the Beadle (1987) in g m^{-2} day^{-1}.

At maturity total number of plants and cobs from each plot were counted and then cob number per plant was calculated. Six crop rows from each sub plot was harvested by hand at soil level and allowed to sun dry under for a week, then cob were dehusked, dried, shelled and weighted. Dry grain weight values were converted on hectare basis and adjusted to standard moisture of 13 %. A sub-sample of 200 grains was used to record the thousand-grain weight. Average grain weight per cob was calculated from the total weight of grains of ten randomly selected cobs from each plot. Data collected were statistically analyzed using MSTAT statistical package (Michigan State University, 1986) and the Least Significant Difference (LSD) test was used to separate the statistically significant means.

Results

Total weed density: The number of weeds per unit area was not affected significantly in 2003 (Table 1) but during 2004 the data indicate that wider rows favoured the weed density. Weed population (mean of two years) of 151.8, 140.6 and 138.0 plants m^{-2} was recorded from plots planted in 75, 65 and 55 cm spaced rows (S_1, S_2 and S_3), respectively.

Duration of weed infestation had significant effect on total weed density per unit area. The highest number of weeds was recorded from plots where weeds were allowed to compete with maize for 30 DAE (C_3) which was statistically at par with 45, 60 DAE and full season competition (C_4, C_5 and C_6) in 2003 and with 45 and 60 DAE competition (C_4 and C_5) in 2004.

Dry weight of weeds (g m^{-2}): Row spacing, weed competition durations and their interactive effects significantly affected dry weight of weeds per unit area (Table 1). In 2003, significantly maximum dry weight of weeds (206.20 g m^{-2}) was recorded from 75 cm row spacing in combination with full season weed-crop competition (S_1C_6) followed by weed dry weight of 160.80 g m^{-2} observed from 75 cm spaced rows and weed competition for 60 DAE (S_1C_5).

Table 1. Effect of row spacing and weed competition durations on weed population and dry weight (g m^{-2}).

	Weed Density (m^{-2})			Dry weight of weeds (g m^{-2})		
Treatments	**2003**	**2004**	**Mean**	**2003**	**2004**	**Mean**
A. Row spacing (cm)						
S_1 = 75	150.67	153.40 a	151.8 a	102.30 a	101.80 a	102.00 a
S_2 = 65	139.54	141.10 b	140.6 ab	81.02 b	76.84 b	78.93 b
S_3 = 55	138.91	137.30 b	138.1 b	67.46 c	68.18 c	67.82 c
LSD	**NS**	**6.37**	**11.26**	**5.06**	**8.47**	**6.17**
B. Weed competition duration						
C_1 = Weed free	0.00 c	0.00 d	0.00 d	0.00 e	0.00 d	0.00 d
C_2 = 15 DAE	80.58 b	86.08 c	83.33 c	5.56 e	5.44 d	5.50 d
C_3 = 30 DAE	197.90 a	201.30 a	199.60 a	92.43 d	93.39 c	92.91 c
C_4 = 45 DAE	197.30 a	199.40 a	198.30 a	115.00 c	115.60 b	115.30 b
C_5 = 60 DAE	195.20 a	198.70 a	196.90 a	130.70 b	118.80 b	124.70 b
C_6 = Weedy check	186.30 a	179.10 b	182.70 b	157.80 a	160.30 a	159.00 a
LSD	**11.84**	**13.52**	**12.53**	**8.81**	**13.87**	**11.47**
C. Interaction						
S_1C_1	0.00	0.00	0.00	0.00 g	0.00 f	0.00 g
S_1C_2	86.00	95.25	90.88	9.88 g	9.02 f	9.45 g
S_1C_3	202.75	205.25	204.00	99.34 f	101.50 de	100.40 e
S_1C_4	212.50	218.50	215.50	137.30 cd	139.50 bc	138.40 c
S_1C_5	204.50	210.00	207.30	160.80 b	154.80 b	157.80 b
S_1C_6	194.75	191.25	193.00	206.20 a	205.70 a	206.00 a
S_2C_1	0.00	0.00	0.00	0.00 g	0.00 f	0.00 g
S_2C_2	78.75	81.75	80.25	3.45 g	3.72 f	3.58 g
S_2C_3	198.75	204.25	201.50	92.78 f	93.04 e	92.91 ef
S_2C_4	187.00	199.50	193.30	116.10 e	118.90 cd	117.50 d
S_2C_5	187.75	190.75	189.30	131.50cd	104.78 de	118.10 d
S_2C_6	185.00	173.25	179.10	142.30 c	140.70 bc	141.50 c
S_3C_1	0.00	0.00	0.00	0.00 g	0.00f	0.00 g
S_3C_2	76.50	81.25	78.88	3.35 g	3.57 f	3.46 g
S_3C_3	192.25	194.50	193.40	85.16 f	85.65 e	85.40 f
S_3C_4	192.25	180.25	186.30	91.64 f	88.55 e	90.10 ef
S_3C_5	193.25	195.25	194.30	99.77 f	96.94 de	98.36 ef
S_3C_6	179.75	172.75	176.00	124.80 de	134.40 bc	129.60 cd
LSD	**NS**	**NS**	**NS**	**15.27**	**24.03**	**14.04**

Values followed by the same letters do not differ significantly at 5 % probability level.
LSD= Least significant difference at 5% probability level.
NS= Non-significant.
DAE= Days after emergence.

Leaf area index (LAI): The data regarding leaf area index (LAI) of maize recorded in 2003 and 2004 at final harvest (75 DAE) are depicted in Table 2. It is evident from data that interactive effects and individual effects of row spacing and weed competition durations on LAI of maize were significant during both the years of study. In 2003, maximum LAI values were observed in weed free crop sown in any row spacing, but in 2004 significantly maximum LAI (6.45) was recorded in weed free crop sown in 55 cm spaced rows (S_3 C_1) as compared with all other treatments. In both years, minimum but statistically similar values of LAI were recorded from plots with treatment combinations of 75 cm and 55 cm spaced rows and weed-crop competition for full season (S_1C_6 and S_3 C_6).

Table 2. Effect of row spacing and weed competition durations on leaf area index and crop growth rate of maize.

Treatments	Leaf area index			Crop growth rate (g m $^{-2}$day^{-1})		
	2003	2004	Mean	2003	2004	Mean
A. Row Spacing (cm)						
S_1 = 75	4.92 a	4.75 b	4.83 a	21.85 b	22.05 a	21.59 a
S_2 = 65	4.86 b	4.73 b	4.79 b	22.30 a	21.89 b	22.10 b
S_3 = 55	4.89 b	4.85 a	4.85 a	22.56 a	22.31 a	22.43 a
LSD	**0.02**	**0.04**	**0.03**	**0.34**	**0.17**	**0.29**
B. Weed competition duration						
C_1 = weed free	6.46 a	6.27 a	6.36 a	28.53 a	28.42 a	28.48 a
C_2 = 15 DAE	5.90 b	5.86 b	5.88 b	26.72 b	26.80 b	26.76 b
C_3 = 30 DAE	5.00 c	4.91 c	4.95 c	22.02 c	22.10 c	22.06 c
C_4 = 45 DAE	4.60 d	4.37 d	4.48 d	19.06 d	19.64 d	19.62 d
C_5 = 60 DAE	3.73 e	3.71 e	3.72 e	18.61 d	18.25 e	18.43 e
C_6=Weedy check	3.55f	3.54f	3.55 f	17.97 e	17.10 e	17.54 f
LSD	**0.05**	**0.06**	**0.05**	**0.52**	**0.32**	**0.42**
C. Interaction						
S_1C_1	6.45 a	6.14 b	6.29 b	28.87 a	29.07 a	28.97 a
S_1C_2	5.99 b	5.93 c	5.96 c	26.43 c	27.12 b	26.78 cd
S_1C_3	5.00 d	4.93 f	4.97g	21.93 d	22.87 d	22.40 e
S_1C_4	4.74 e	4.31 I	4.52 i	18.93 fg	19.30 h	19.12 i
S_1C_5	3.73 g	3.69 j	3.71 k	17.68 fgh	17.18 i	17.43 j
S_1C_6	3.53 i	3.51 k	3.52 m	17.35 i	16.78 i	17.06 j
S_2C_1	6.43 a	6.21 b	6.32 b	28.19 bc	27.72 ab	27.95 bc
S_2C_2	5.84 c	5.78 d	5.81 e	26.79 bc	26.66 c	26.72 d
S_2C3	4.97 d	4.75 g	4.86 h	21.78 d	21.33 f	21.55 g
S_2C_4	4.50 f	4.27 I	4.38 j	19.92 e	19.53 gh	19.72 h
S_2C_5	3.76 g	3.69 j	3.73 k	18.72 gh	15.12 i	16.92 j
S_2C_6	3.63 h	3.65 j	3.64 l	18.43 gh	14.35 j	16.39 k
S_3C_1	6.50 a	6.45 a	6.47 a	28.53 ab	28.48 ab	28.50 ab
S_3C_2	5.88 c	5.88 cd	5.88 d	26.94 bc	26.63 c	26.79 d
S_3C_3	5.03 d	5.04 e	5.04 f	22.34 d	22.09 e	22.22 f
S_3C_4	4.55 f	4.53 h	4.54 i	19.95 e	20.10 g	20.03 h
S_3C_5	3.70 gh	3.74 j	3.72 k	19.43 ef	19.11 h	19.27 i
S_3C_6	3.49i	3.46 k	3.48 m	18.18 h	17.48 i	17.83 j
LSD	**0.08**	**0.10**	**0.06**	**0.90**	**0.52**	**0.56**

Values followed by the same letters do not differ significantly at 5 % probability level.
LSD= Least significant difference at 5% probability level.
NS= Non-significant.
DAE= Days after emergence.

Crop growth rate (CGR): The data regarding crop growth rate (CGR) of maize (Table 2) reveal that interactive and main effects of row spacing and weed competition duration were significant during both the years of study. In both years, maximum CGR was recorded in weed free crop sown in 75 cm row spacing (S_1C_1). It was statistically at par with weed free crop sown in 55 cm spaced rows (S_3C_1) during 2003 but also statistically similar with weed free crop sown in 65 or 55 cm spaced rows in 2004 (S_2C_1 and S_3C_1). In 2003, significantly minimum CGR was recorded when crop was sown in 75 cm spaced rows with full season weed competition (S_1C_6), while in 2004 the minimum CGR was recorded in crop sown in 65 cm spaced rows and followed to compete with weeds for full season (S_2C_6).

Number of cobs per plant: The number of cobs per plant was significantly affected by different row spacing as well as by the duration of weed competition in both the years (Table 3). The significantly highest number of cobs per plant (1.62) was recorded in crops sown in 75 cm spaced rows (S_1) and (2.14 plant^{-1}) in weed free crop (C_1). The interaction between row spacing and weed competition duration was significant during 2004 only. A perusal of data (two year means) reveals that crop kept weed free after sown in 75 cm spaced rows (S_1C_1) produced the highest (2.36) average number of cobs per plant followed by weed free crop sown in 65 and 55 cm spaced rows (S_2 $C_1$and S_3 C_1). The lowest number of cobs per plant was recorded in plots where weeds were allowed to grow until harvest or for 60 DAE in combination with any of row spacing.

Grain weight per cob: Row spacing and interactive effect of row spacing and weed competition durations had a non-significant effect on grain weight. Whereas the weed crop competition durations significantly affected the grain weight (Table 3). Maximum grain weight per cob was recorded from weed free (C_1) treatments followed by 15 DAE competition (C_2) in both years. There was substantial reduction in grain weight per cob for other duration of weed competition. In both years minimum grain weight per cob was recorded in weedy check (C_6) where weeds competed with maize for full season..

1000-grain weight: The grain size contributes considerably towards final grain yield of maize. Data shown in Table 3 indicate that row spacing significantly affected the 1000-grain weight of maize during 2003 but non-significant affect was observed in 2004. Mean values for two years indicate that wider row spacing (75 and 65 cm) produced heavier grain compared to the narrower ones (55 cm spaced rows). The effect of weed competition durations was also significant during both years of study. Maximum 1000-grain weight was obtained from weed free crop (C_1) and the crop, which faced the least competition i.e., for 15 DAE (C_2). The lowest 1000-grain weight was observed in weedy check (C_6) where weeds competed with maize for full season.

The interaction of row spacing and weed competition duration was significant during 2003 only. Mean values indicate that highest 1000-grain weight (260.40 g) was recorded in plots sown in 65 cm spaced rows and kept free of weeds (S_2 C_1) and was statistically at par with 65 cm wide row spacing and kept weed free 15 DAE competition (S_2 C_2). The results of these combinations were followed by 75 and 55 cm spaced rows (S_1C_1, S_1C_2, S_3 C_1 and S_3 C_2) each in combination with weed free treatment and 15 DAE competition. These combinations were at par with each other. The lowest 1000-grain weight was recorded from weedy check with 55 cm spaced rows (S_3 C_6).

Grain yield (t ha^{-1}): Grain yield per unit area is a function of interaction among various yield-contributing factors, which are affected differentially by the growing conditions and crop management practices. Data pertaining to the grain yield (Table 3) indicate that it was not affected significantly by any of the row spacing. However, the range of grain yield produced due to different row spacing was 5.31-5.51 t ha^{-1}. In contrast, duration of weed competition affected the grain yield significantly during both the years. The significantly maximum amount of grain yield (6.86 t ha^{-1}) was recorded from the weed free crop (C_1) against the significantly minimum grain yield (3.39 t ha^{-1}) obtained from the weedy check (C_6) in 2003. Almost similar trend was noted in 2004.

The interactive effect of various treatments in respect to grain yield was highly significant during 2004 only. Crop sown on 55 cm spaced rows and kept weed free (S_3 C_1) produced the maximum grain yield (7.66 t ha^{-1}), which was statistically at par with yield obtained from 55 cm spaced rows with weed free (S_3 C_1) or competition for 15 DAE (S_3 C_2) and 75 cm spaced rows with weed free conditions (S_1C_1) and 65 cm spaced rows with weed free conditions (S_2 C_1)

Discussion

These results clearly show that narrow row spacing has suppressed the weeds as compared to wider row spacing. This might be due to early crop canopy closure so weed plants could not get sufficient amount of solar radiation for their survival and ultimately resulted in less number of weed plants per unit area. Generally there was an increase in weed population up to 30 DAE (C3), which then become constant. Numbers of weeds at 30 DAE indicate their peak germination time indicating the need of early weeding in maize. Gab-Alla *et al*, (1985) reported that early weeding in maize caused a significant depression in weed number. Decrease in dry weight of weeds with decreased spacing was due to decrease in weed number and fresh weight. Suppression in weed biomass by reducing row spacing from 56 to 38 cm was also reported by Begna *et al.*, (2001), Stewart (2001) and that of Tharp and Kells, (2001). More dry weight of weeds in full season competition than other treatments was simply due to longer competition period available to weeds in this treatment.

In narrow row spacing increase in LAI may be attributed to less number of weeds and their dry weights, so as a result crop plants utilized maximum applied nutrients. These results are in line with those of Murphy *et al.*, (1996) who reported that increasing the corn density from 7-10 plants m^{-2} or decreasing the row width from 75-50 cm significantly increase the corn leaf area index (LAI), reduced the biomass of late emerging weeds and photon flux density (PPFD) available for a mixture of weed species located below the corn canopy. Utilization of all environmental resources by crop plants in weed free treatments could be the reason of high LAI of maize for this treatment. Decrease in LAI with increase in competition duration seems to be the result of decreased supply of moisture and nutrients. The results of this study are in good agreement with those of reported by Irshad (2000). Higher CGR in wider row spacing may be attributed to availability of more environmental resources than narrow rows, which enabled crop to accumulate more dry weight per unit area and hence faster CGR. However, These results does not support the findings of Zaman and Maity (1988) who reported that reducing row spacing had non significant effects on CGR of maize. Decrease in CGR with increase in weed competition duration was due to increased competition of weeds with maize for different growth factors. Zanin *et al.*, (1988) reported that competition of weeds with maize crop for 54 days reduced maize growth rate considerably than weed free conditions.

More number of cobs plant^{-1} in 75 cm spaced rows indicate that wider row spacing were more appropriate for maize crop most probably due to more resources available and their best utilization. Decrease in number of cobs plant^{-1} with an increase in weed competition duration was due to competition of weeds with maize for different environmental factors for a longer time. Nawab *et al.*, (1999) also reported reduction in number of cobs plant^{-1} in heavily weedy crop. Maximum grain weight per cob in weed free treatments again could be due to best utilization of available soil and climatic resources by maize plant in the absence of weeds. Reduction in grain weight per cob due to weed infestation has also reported by earlier researchers i.e. Khalid and Shah (1987) and Akthar *et al.*, (1994). Improvement in widely spaced plants might be due to enhanced grain development and filling in response to better utilization of growth resources. Decrease in 1000-grain weight with decrease in row spacing might be due to intra-plant competition for climatic resources. Decrease in LAI, CGR could be the reason of low 1000-grain weight in treatments where weeds competed with maize for a longer duration. Reduction in maize seed weight due to weed infestation was also reported by Johnson *et al.*, (1998). Maximum grain yield in weed free conditions was associated with more number of cobs per plant, more grain weight per cob and 1000-grain weigh. Conversely the decrease in maize yield in weedy crop is ascribed to reduction in CGR that ultimately reduced the grain weight per cob. These results are supported by those of Hatam & Khattak (1994), Ansar *et al*., (1996) and Kumar & Sundari (2002). It is concluded that row spacing of 55 cm in maize was effective in suppressing weeds and the maximum weed density and biomass recorded at 30 days after emergence indicate the need of early weeding in maize.

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