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UTILIZATION OF ALLELOPATHY AND PLANTING GEOMETRY FOR WEED MANAGEMENT AND DRY MATTER PRODUCTION 0F MAIZE

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Abstract

Undesirable impact of herbicides on environment had led to the efforts to search for alternative of herbicides. Allelopathy and planting geometry are possible alternatives for achieving sustainable weed management and dry matter production. The objective of this study was to evaluate the response of maize to allelopathy and planting geometry. Maize was planted in 75, 85 and 95 cm apart rows at New Developmental Farm, NWFP Agricultural University, Peshawar during 2006. Three allelopathic crops, sorghum (*Sorghum bicolor L.*), sunflower (*Helianthus annuus* L.) and mungbean (*Vigna radiate Wilczek*) were intercropped in maize rows alongwith sole maize with no weeding (control) and sole maize with hand weed control. Row spacing and allelopathic crops significantly affected plant height, weeds density and weeds biomass. Maize row spacing of 75 cm produced taller plants height (161.0 cm) and maximum stalk (7093.7 kg ha^{-1}), whereas in allelopathic crop treatments, maximum plant height (170.9 cm) and stalk yield (8854.1 kg ha^{-1}) were produced by hand weed control treatment. Sorghum intercropped with maize suppressed weeds density and resulted in low biomass of deela (*Cyprus rotundus* L.), field bind weed (*Convolvulus arvensis* L.) and itsit (*Trianthema portulacastrum* L.) compared with other treatments. It may be inferred from this study that weeds were better suppressed by 75 cm row spacing and sorghum intercropped plots.

Introduction

Maize (*Zea mays* L.) is the most important cereal crop of the world grown in the irrigated and rainfed areas. It is a rich source of food, fodder, feed and provides raw material for the industry (Nazir *et al*., 1994). Corn oil is becoming popular due to its non-cholesterol character. In addition, its products like corn starch, corn flakes, gluten germ-cake, lactic-acid, alcohol and acetone are either directly consumed as food or used by various industries like paper textile, foundry and fermentation (Nazir *et al.*, 1994). Corn yield per unit area is still far below its yield potential obtained in other corn producing countries (MINFAL, 2007).

Row spacing is one of the important management factors affecting agronomic and physiological parameter of corn. Decreasing the distance between rows at any particular plant population may reduce competition among plants within rows for light, water and nutrients (Olson & Sander, 1988) and produce higher biological, grain and stalk yield (Shah *et al*., 2001; Martin *et al*., 2003). The more favorable planting pattern provided by closer rows enhances maize growth rate early in the season (Bullock *et al*., 1988), leading to a better interception of sun light, a higher radiation use efficiency and a greater dry matter production (Fernando *et al*., 2001; Westgate *et al*., 1997). Reduced row spacing can provide the crop with a competitive advantage over weeds by producing lighter weeds (Weaver, 1991). Reducing the row spacing may provide a cultural control measure to help manage herbicide resistant weed. Studies investigating the effect of maize row spacing on weed growth revealed that weed biomass was decreased 28% by reducing row spacing to 56 cm and by 16 to 29% in 38 cm rows (Maqbool *et al*., 2006). The reduced weed growth in narrow rows may be due to reduced light penetration to the weeds emerging below the crop canopy. Several studies have shown that narrow rows were efficient in terms of light interception than wider rows (Begna *et al*., 2001). However, research elsewhere (Minnesota) revealed that reducing row spacing had no significant impact on weed biomass (Johnson *et al*., 1998).

Infestation with weeds is one of the most serious factor reducing the growth and dry matter production of maize. Herbicides are effective in controlling weeds yet their unwise use may disturb the ecosystem by increasing soil and water pollution (Ahmad *et al*., 2000). Because of environmental and human health concerns, worldwide efforts are underway to reduce the heavy reliance on synthetic herbicides that are used to control weeds. Allelopathy is considered to be one of the possible alternatives for achieving sustainable weed management (Hussain *et al*., 2007; Singh *et al*., 2003; Cheema, 1988). Allelopathy may play a beneficial role in various cropping systems such as mixed cropping, multiple cropping, cover cropping, crop rotation and minimum and no tillage system (Leather, 1983). Allelopathy is an interaction between plants where compounds such as tannins, alkaloids and phenolic acids produced by one plant are released into the environment and inhibit or stimulate the growth of another plant (Rice, 1984). The present project was therefore initiated to evaluate planting geometry and allelopathic effect of various crops on weeds density, biomass and stalk yield of maize.

Materials and Methods

Effect of allelopathic crops and planting geometry on weed management and dry matter yield of maize was studied at New Developmental Farm, NWFP Agricultural University Peshawar during summer 2006. Maize was planted in three different planting geometry at 75, 85 and 95 cm apart rows and three allelopathic crops viz., sorghum, sunflower and mungbean were intercropped in maize. Two more treatments that is no weeding (control) were also included in the experiment planted on 4th July 2006 according to randomized complete block design with split plot arrangement having four replications. Row spacing were assigned to main plots while allelopathic crops were allotted to sub plots having sub plot area of 4.8 x 5 m having 5 m long rows. Maize variety Azam was sown 30 kg ha^{-1}, while sorghum variety DS 2003, sunflower variety M 20016 and mungbean variety Karak Mung 1 were intercropped between the rows of maize in their assigned plots @ 16, 6 and 18 kg ha^{-1} respectively on the same date. In control plots sole maize was planted and no other crop was intercropped. There were two control treatments that is no weeding and hand weeding. In control hand weeding was done 15, 30 and 45 days after sowing. A basic dose of 120:50:60 kg NPK was applied. Phosphorous ($P2O_5$) was applied in the form of Single Supper Phosphate, while potash was applied in the form of murate of potash at sowing time. Nitrogen was applied in the form of urea. Half of nitrogen was applied at the time of sowing while the remaining half of nitrogen was applied at knee height stage. All other agronomic practices were kept uniform for all treatments. Data were recorded on weeds density m^{-2}, and weed biomass m^{-2} at 15, 30 and 45 days after sowing plant height and stalk yield.

Weeds density: Weed density was calculated by throwing quadrate measuring 1 m^2 two times in each subplot. The weeds that came under the quadrate were identified; their numbers were counted separately for each weed. This procedure was repeated three times 15, 30 and 45 days after sowing.

Weeds biomass: The weeds within the quadrate were collected and their fresh weeds weight in g m^{-2} was recorded with electronic balance.

Plant height: Ten plants were randomly selected from each subplot at maturity and their height was recorded. Measurements were taken in cm from the soil surface to the tip of the plant with a meter rod.

Stalk yield: Ears from two central rows were removed, stalks were harvested, sun dried for two weeks and weighed with spring balance and converted into kg ha^{-1}.

Statistical analysis: Data collected were analyzed statistically according to randomized complete block design with split plot arrangement. Means were compared using Least Significance Difference (LSD) test at 0.05 level of probability when the F-values were significant (Steel & Torrie, 1984).

Results

Weeds density

Number of *Cyprus rotundus:* Statistical analysis of the data revealed that row spacing (R), allelopathic crops (A), weeds collection stage (S), interaction of RxA, R x S, A x S and R x A x S significantly affected number of (deela) *Cyprus rotundus* (Table 1). Maximum number of weed deela (81.2) was recorded in 95 cm apart rows, while minimum number of deela (76.0) were recorded in narrow row spacing of 75 cm apart rows (Table 2). In case of allelopathic crops highest number of deela (148.0) were recorded in control (no weed control), while lowest number of deela (70.4) were observed from maize intercropped with sorghum crop. Mean values for seeds collection stages showed that lowest number of deela (41.2) was recorded 15 days after sowing. Weeds density increased with each stage and maximum number of deela (113.6) was recorded 45 days after sowing.

Interaction between R x A showed that maximum number of deela (160.0) were recorded from 95 cm apart rows with no weed control, while minimum number of deela (67.2) were recorded in 85 cm apart rows of maize intercropped with mungbean. In case of R x S interaction minimum number of deela (36.8) was noted from 75 cm apart rows at 15 days after sowing, while maximum number of deela (116.4) was recorded from 95 cm apart rows at 45 days after sowing.

Number of *Convolvulus arvensis*: Row spacing (R), allelopathic crops (A), weeds collection stage (S), interaction of R x A, R x S, A x S and R x A x S significantly affected number of *Convolvulus arvensis* (Table 1). Mean values of row spacing showed that maximum number of *Convolvulus arvensis.* (31.2) were recorded from 95 cm apart rows, while 75 cm apart rows showed minimum number (25.6) of weed (Table 3). Mean values of allelopathic crops showed that sorghum crop reduced weeds density and resulted in minimum number of *Convolvulus arvensis* (18.4), while plots without weed control produced maximum number of weeds (66.8).

Table 1. Mean squares for *Cyprus rotundus*, *Convulvulus arvensis* and *Trianthema portulacastrum* as affected by row spacing, allelopathic crops and weed collection stages.

Source	Degree of Freedom	Mean squares		
		Cyprus rotundus	*Convulvulus arvensis*	*Trianthema portulacastrum*
Replication	3	116.0	32.4	19.7
Row spacing (R)	2	27.1**	28.1**	24.1**
Error I	6	7.7	0.6	1.1
Allelopathic crop (A)	4	6285.7**	1345.8**	322.4**
R X A	8	46.6**	3.4*	2.6*
Stages (S)	2	4875.4**	997.9**	1019.7**
R X S	4	3.6 ns	5.0*	6.0*
A X S	8	347.6**	150.8**	119.4**
R X A X S	16	11.9 ns	0.8 ns	1.3 ns
Error II	126	8.8	1.0	1.3
Total	**179**			

CV = 15.26%
** = Significant at 5% probability level
Ns = Non significant

Table 2. Number of *Cyprus rotundus* (m^{-2}) in maize as affected by row spacing, allelopathic crops and weed collection stages.

Row spacing (cm)	Allelopathic crops intercropped in maize	Days after sowing			Means
		15	30	45	
75	No weeding	85.2	134.0	174.0	131.2b
	Sorghum	33.2	65.6	116.0	71.6cd
	Sunflower	39.2	91.6	130.4	87.2c
	Mungbean	27.6	100.4	140.4	89.6c
	Hand weeding	0.0	0.0	0.0	0.0e
85	No weeding	94.4	160.4	203.6	152.8a
	Sorghum	30.4	63.6	108.0	67.2d
	Sunflower	52.4	91.6	127.6	90.4c
	Mungbean	30.4	80.4	119.6	76.8cd
	Hand weeding	0.0	0.0	0.0	0.0e
95	No weeding	95.2	169.2	216.0	160.0a
	Sorghum	36.4	68.0	112.0	72.0cd
	Sunflower	56.4	80.4	120.4	86.4cd
	Mungbean	38.0	89.6	133.2	86.8c
	Hand weeding	0.0	0.0	0.0	0.0e
75		36.8	78.4	112.0	76.0b
85		41.6	79.2	111.6	77.6b
95		45.6	81.6	116.4	81.2a
	No weeding	91.6	154.4	198.0	148.0a
	Sorghum	33.2	65.6	112.0	70.4c
	Sunflower	50.0	88.0	126.0	88.0bc
	Mungbean	32.0	90.0	131.2	84.0d
	Hand weeding	0.0	0.0	0.0	0.0d
	Mean	**41.2c**	**79.6b**	**113.6a**	

LSD value at p=0.05 for row spacing=3.502, allelopathic crops=4.859, stages=3.648, RxA=4.170, RxAxS=4.467
Means followed by different letters are significantly different from each other at 5% level of probability using LSD test.

Table 3. Number of *Convulvulus arvensis* (m^{-2}) of maize as affected by row spacing, allelopathic crops and 15, 30 and 45 days weeds collection stages after sowing.

Row spacing (cm)	Allelopathic crops intercropped in maize	Days after sowing			Means
		15	30	45	
75	No weeding	29.6	58.0	99.2	62.0b
	Sorghum	6.0	16.0	25.2	15.6h
	Sunflower	10.0	26.0	35.2	23.6efg
	Mungbean	11.2	30.0	39.2	26.8cdef
	Hand weeding	0.0	0.0	0.0	0.0i
85	No weeding	28.0	62.0	105.2	65.2b
	Sorghum	5.6	20.0	29.2	18.0gh
	Sunflower	10.4	30.0	38.4	26.4def
	Mungbean	9.6	33.6	51.2	31.2cd
	Hand weeding	0.0	0.0	0.0	0.0i
95	No weeding	33.6	70.0	116.0	73.2a
	Sorghum	6.0	24.0	33.2	21.2fgh
	Sunflower	11.6	34.0	42.4	29.2cde
	Mungbean	11.2	38.4	47.2	32.0c
	Hand weeding	0.0	0.0	0.0	0.0i
75		11.2	26.0	39.6	25.6c
85		10.8	29.2	44.8	28.0b
95		12.4	33.2	47.6	31.2a
	Control without hoeing	30.4	63.2	106.8	66.8a
	Sorghum	6.0	20.0	29.2	18.4c
	Sunflower	10.8	30.0	38.8	26.4b
	Mungbean	10.4	34.0	45.6	30.0b
	Control with hoeing	0.0	0.0	0.0	0.0d
	Mean	**11.6c**	**29.6b**	**44.0a**	

LSD value at p=0.05 for row spacing=1.246, allelopathic crops=1.319, stages=1.215, RxA=1.110, RxAxS=1.428
Means followed by different letters are significantly different from each other at 5% level of probability using LSD test.

Interaction between R x A revealed that maximum number of *Convolvulus arvensis* (73.2) was recorded from 95 cm apart rows with no weed control whereas minimum number of *Convolvulus arvensis* (15.6) was noted from 75 cm apart rows of maize intercropped with sorghum. The interaction between R x S showed that maximum number of *Convolvulus arvensis* (47.6) was noted from 95 cm apart rows counted 45 days after sowing, while minimum number of *Convolvulus arvensis* (26.0) was recorded from 85 cm apart rows at 15 days after sowing.

Number of *Trianthema portulacastrum:* Analysis of the data showed that row spacing (R), allelopathic crops (A), weeds collection stage (S), interaction of R x A, R x S, A x S and R x A x S significantly affected number of *Trianthema portulacastrum (itsit* weed*)* (Table 1). Maximum number of itsit (16.4) was recorded from 95 cm apart rows, while minimum number of itsit (13.6) was collected from 75 cm apart rows (Table 4). Sorghum intercropped with maize suppressed weeds and produced minimum of itsit (10.4), while control (no weed control), produced highest number of itsit (32.8).

Interaction between R x A showed that maximum number of 36.8 was recorded from 95 cm apart row with no weed control, while minimum number of itsit (9.2) was recorded in 75 cm apart rows of maize intercropped with sorghum. The interaction between R x S revealed that maximum number of itsit (36.4) was noted from 95 cm row spacing collected 45 days after sowing while minimum number of Itsit (10.8) was recorded from 85 cm row spacing collected 15 days after sowing.

Table 4. Number of *Trianthema potulacastrum* (m^{-2}) of maize as affected by row pacing, allelopathic crops and 15, 30 and 45 days weeds collection stages after sowing.

Row spacing (cm)	Allelopathic crops intercropped in maize	Days after sowing			Means
		15	30	45	
75	No weeding	0.0	29.6	63.2	30.8a
	Sorghum	0.0	6.0	22.0	9.2d
	Sunflower	0.0	10.0	25.6	12.0cd
	Mungbean	0.0	11.2	35.2	15.2bcd
	Hand weeding	0.0	0.0	0.0	0.0e
85	No weeding	0.0	28.0	64.4	30.8a
	Sorghum	0.0	5.6	25.2	10.0d
	Sunflower	0.0	10.4	29.2	13.2bcd
	Mungbean	0.0	9.6	47.2	18.8b
	Hand weeding	0.0	0.0	0.0	0.0e
95	No weeding	0.0	33.6	77.2	36.8a
	Sorghum	0.0	6.0	29.2	11.6cd
	Sunflower	0.0	11.6	35.2	15.6bcd
	Mungbean	0.0	11.2	41.6	17.6bc
	Hand weeding	0.0	0.0	0.0	0.0e
75		0.0	11.2	29.2	13.6c
85		0.0	10.8	33.2	14.8b
95		0.0	12.4	36.4	16.4a
	No weeding	0.0	30.4	68.0	32.8a
	Sorghum	0.0	6.0	25.2	10.4c
	Sunflower	0.0	10.8	30.0	13.6bc
	Mungbean	0.0	10.4	41.2	17.2b
	Hand weeding	0.0	0.0	0.0	0.0d
	Mean	**0.0 c**	**11.6b**	**32.8a**	

LSD value at p=0.05 for row spacing=1.100, allelopathic crops=1.103, stages=1.310, RxA=1.201, RxAxS=1.571
Means followed by different letters are significantly different from each other at 5% level of probability using LSD test.

Biomass yield

Biomass yield of *Cyprus rotundus:* Row spacing (R), allelopathic crops (A), weeds collection stage (S), interaction of R x A, R x S, A x S and R x A x S significantly affected biomass of *Cyprus rotundus (deela)* (Table 5). Maximum biomass of deela (89.6 g) was recorded from 95 cm row spacing, while minimum biomass of deela (81.2 g) was recorded from 75 cm spacing (Table 6). Mean values for allelopathic crops showed that highest biomass of deela (156.4 g) was recorded from control (no weed control) while lowest biomass of deela (80.8 g) was observed from maize intercropped with sorghum. Lowest biomass of deela (93.2 g) was recorded 15 days after sowing which increased with time and maximum biomass (127.6 g) was recorded 45 days after sowing.

Mean values for R x A interaction showed that maximum biomass of deela (171.2 g) was recorded from 95 cm x control, while minimum biomass of deela (76.4 g) was recorded from 85 cm apart rows of maize intercropped with sorghum. In case of R x S interaction minimum biomass of deela (32.4 g) was recorded from 75 cm row spacing collected 15 days after sowing, whereas maximum biomass of deela (133.2 g) were noted from 95 cm row spacing collected 45 days after sowing.

Table 5. Mean squares for biomass of Cyprus rotundus, Convulvulus arvensis and Trianthema portulacastrum as affected by row spacing, allelopathic crops and weed collection stages.

Source	Degree of Freedom	Mean squares		
		Cyprus rotundus	*Convulvulus arvensis*	*Trianthema portulacastrum*
Replication	3	182.9	30.3	13.9
Row spacing (R)	2	64.8*	27.6**	13.1**
Error I	6	12.0*	0.8	0.4
Allelopathic crop (A)	4	7059.1**	1553.8**	395.3**
R X A	8	59.5**	4.4**	1.5**
Stages (S)	2	7394.1**	1847.3**	1724.5**
R X S	4	12.4 ns	3.8*	5.7**
A X S	8	496.3**	205.0**	164.2**
R X A X S	16	7.4 ns	0.7 ns	1.1 ns
Error II	126	10.4	1.1	1.2
Total	**179**			

CV = 12.87%

Table 6. Biomass of *Cyprus rotundus* (g m^{-2}) in maize as affected by row spacing, allelopathic crops and weed collection stages.

Row spacing (cm)	Allelopathic crops intercropped in maize	Days after sowing			Means
		15	30	45	
75	No weeding	74.0	143.6	190.4	136.0b
	Sorghum	25.6	86.4	132.8	81.6cd
	Sunflower	32.0	98.8	147.2	92.8cd
	Mungbean	29.6	110.8	150.4	96.8c
	Hand weeding	0.0	0.0	0.0	0.0e
85	No weeding	93.2	172.0	220.8	162.0a
	Sorghum	28.8	75.2	126.0	76.4d
	Sunflower	49.2	97.6	144.4	97.2c
	Mungbean	26.8	88.8	137.6	84.4cd
	Hand weeding	0.0	0.0	0.0	0.0e
95	No weeding	100.4	178.8	234.8	171.2a
	Sorghum	38.0	80.4	135.6	84.8cd
	Sunflower	60.4	90.8	146.8	99.2c
	Mungbean	30.4	98.0	149.6	92.8cd
	Hand weeding	0.0	0.0	0.0	0.0e
75		32.4	88.0	124.0	81.2b
85		39.6	86.8	125.6	84.0b
95		46.0	89.6	133.2	89.6a
	No weeding	89.2	164.8	215.2	156.4a
	Sorghum	30.8	80.8	131.6	80.8b
	Sunflower	47.2	95.6	146.0	96.4b
	Mungbean	28.8	99.2	146.0	91.2b
	Hand weeding	0.0	0.0	0.0	0.0c
	Mean	**39.2c**	**88.0b**	**127.6a**	

LSD value at p=0.05 for row spacing=4.215, allelopathic crops=4.350, stages=4.512, RxA=4.124, RxAxS=4.512
Means followed by different letters are significantly different from each other at 5% level of probability using LSD test.

Table 7. Biomass of *Convulvulus arvensis* (g m^{-2}) in maize as affected by row spacing, allelopathic crops and weed collection stages.

Row spacing (cm)	Allelopathic crops intercropped in maize	Days after sowing			Means
		15	30	45	
75	No weeding	25.2	64.4	112.8~	67.6b
	Sorghum	5.6	22.8	39.2	22.4h
	Sunflower	9.2	30.8	48.8	29.6efg
	Mungbean	10.4	36.0	53.6	33.2cde
	Hand weeding	0.0	0.0	0.0	0.0i
85	No weeding	25.2	68.4	118.8	70.8b
	Sorghum	5.2	26.0	43.2	24.8gh
	Sunflower	10.4	34.4	51.2	32.0def
	Mungbean	8.4	40.8	64.0	37.6cd
	Hand weeding	0.0	0.0	0.0	0.0i
95	No weeding	35.2	76.0	128.8	80.0a
	Sorghum	5.2	29.2	46.4	27.2fgh
	Sunflower	9.6	39.6	56.4	35.2cde
	Mungbean	8.8	44.4	61.2	38.0c
	Hand weeding	0.0	0.0	0.0	0.0i
75		10.0	30.8	50.8	30.4c
85		10.0	34.0	55.6	33.2b
95		11.6	37.6	58.4	36.0a
	No weeding	28.4	69.6	120.0	72.8a
	Sorghum	5.2	26.0	42.8	24.8c
	Sunflower	9.6	34.8	52.0	32.4b
	Mungbean	9.2	40.4	59.6	36.4b
	Hand weeding	0.0	0.0	0.0	0.0d
	Mean	**10.4c**	**34.0b**	**54.8a**	

LSD value at p=0.05 for row spacing=1.105, allelopathic crops=1.591, stages=1.356, RxA=1.426, RxAxS=1.503
Means followed by different letters are significantly different from each other at 5% level of probability using LSD test.

Biomass yield of *Convolvulus arvensis:* Analysis of the data showed that row spacing (R), allelopathic crops (A), weeds collection stage (S), interaction of R x A, R x S, A x S and R x A x S significantly affected biomass of *Convolvulus arvensis* (Table 5).Wider row spacing of 95 cm produced maximum biomass of *Convolvulus arvensis* (36.0 g), while narrow row spacing of 75 cm showed minimum biomass (30.4 g) of *Convolvulus arvensis* (Table 7). Mean values of allelopathic crops showed that maize intercropped with sorghum showed minimum biomass of *Convolvulus arvensis* (24.8 g), while control showed maximum biomass of *Convolvulus arvensis* (72.8 g).

In case of R x A interaction maximum biomass of *Convolvulus arvensis* (80.0 g) was recorded from 95 cm row spacing x control, whereas minimum biomass of *Convolvulus arvensis* (22.4 g) was recorded from 75 cm apart rows of maize intercropped with sorghum. The interaction between R x S revealed that maximum biomass of *Convolvulus arvensis* (58.4 g) was noted from wider spacing of 95 cm apart rows collected 45 days after sowing, while minimum biomass of *Convolvulus arvensis* (10.0 g) was recorded from 85 cm row spacing collected 30 days after sowing.

Table 8. Biomass of *Trianthema portulacastrum* (g m^{-2}) in maize as affected by row spacing, allelopathic crops and weed collection stages.

Row spacing (cm)	Allelopathic crops intercropped in maize	Days after sowing			Means
		15	30	45	
75	No weeding	0.0	27.2	74.8	34.0a
	Sorghum	0.0	12.0	35.2	15.6d
	Sunflower	0.0	16.8	36.8	17.6cd
	Mungbean	0.0	20.0	48.8	22.8bc
	Hand weeding	0.0	0.0	0.0	0.0e
85	No weeding	0.0	28.4	77.6	35.2a
	Sorghum	0.0	13.6	38.0	17.2cd
	Sunflower	0.0	17.6	42.8	20.0cd
	Mungbean	0.0	21.2	46.8	22.4bc
	Hand weeding	0.0	0.0	0.0	0.0e
95	No weeding	0.0	29.6	90.8	40.0a
	Sorghum	0.0	14.0	40.0	18.0cd
	Sunflower	0.0	20.0	48.8	22.8bc
	Mungbean	0.0	26.4	56.0	27.2b
	Hand weeding	0.0	0.0	0.0	0.0e
75		0.0	15.2	39.2	18.0c
85		0.0	16.0	40.8	18.8b
95		0.0	18.0	47.2	21.6a
	No weeding	0.0	28.4	81.2	36.4a
	Sorghum	0.0	13.2	37.6	16.8c
	Sunflower	0.0	18.0	42.8	20.4bc
	Mungbean	0.0	22.4	50.4	24.4b
	Hand weeding	0.0	0.0	0.0	0.0d
	Mean	**0.0 c**	**16.4b**	**42.4a**	

LSD value at p=0.05 for row spacing=0.701, allelopathic crops=1.127, stages=1.526, RxA=0.997, RxAxS=1.541
Means followed by different letters are significantly different from each other at 5% level of probability using LSD test.

Biomass yield of *Trianthema portulacastrum* (itsit): Row spacing (R), allelopathic crops (A), weeds collection stage (S), interaction of R x A, R x S, A x S and R x A x S significantly affected biomass of *Trianthema portulacastrum* (Table 5). Maximum biomass of itsit (21.6 g) was recorded in 95 cm row spacing while minimum biomass of itsit (18.0 g) was recorded in 75 cm row spacing (Table 8). Lowest biomass of itsit (16.8 g) was observed from maize intercropped with sorghum, while highest biomass of itsit (36.4 g) was recorded from control. No weeds were found 15 days after sowing. However, itsit biomass increased with time after sowing and heavy biomass of itsit (42.4 g) was recorded 45 days after sowing.

Mean values for R x A interaction showed that maximum biomass of itsit (40.0 g) was recorded from 95 cm x control treatment, while minimum biomass of itsit (15.6 g) was recorded from 75 cm x maize intercropped with sorghum. The interaction between R x S revealed that maximum biomass of itsit (47.2 g) was noted from 95 cm row spacing collected 45 days after sowing, while minimum biomass of itsit (15.2 g) was recorded in 75 cm row spacing collected 30 days after sowing.

Plant height: Row spacing and allelopathic crops significantly affected plant height, while interaction between R x A was non-significant (Table 9). Mean values for spacing revealed that narrow row spacing of 75cm apart rows resulted in taller plants (161.0 cm). Plant height decreased with increase in row spacing and shorter plants (156.1 cm) were recorded from 95 cm apart rows (Table 10). Manual weed control treatment produced taller plants (170.9 cm), while shorter plants (139.5 cm) were recorded from no weed control treatment.

Stalk yield: Statistical analysis of the data revealed that row spacing and allelopathic crops significantly affected stalk yield, while R x A interaction showed no significant effect on stalk yield (Table 9). Narrow row spacing of 75 cm apart rows produced maximum stalk yield (7093.7 kg ha^{-1}), while 85 cm apart rows produced lowest stalk yield of 6468.7 kg ha^{-1} (Table 11). Maximum stalk yield (8854.1 kg ha^{-1}) was recorded from treatment, while minimum stalk yield (5260.4 kg ha^{-1}) was recorded from no weed control treatment.

Discussion

Fewer weeds (deela) were observed in narrow row spacing compared with wider row spacing. Lowest number of deela at 75 cm row spacing may be due to the fact that narrow row spacing suppressed weeds better than wider row spacing (Maqbool *et al*., 2006). Lowest number of deela was found in maize intercropped with sorghum. Poor suppression of deela in maize inter cropped with sorghum may be due to the fact that deela is grassy weed and could not be effectively controlled by allelopathic crops. This fact is supported by Leather (1983) who concluded that broadleaf weeds can be suppressed by sorghum grown as a cover crop, but with no effect on grassy weeds.

Narrow row spacing of 75 cm apart rows suppressed *Convolvulus arvensis* density more than wider row spacing. This fact is also supported by Naqvi & Sulyman (1962) who reported that weed density decreased by decreasing row spacing. Lowest density of *Convolvulus arvensis* was found in maize intercropped with sorghum. Low density of *Convolvulus* may be due to the fact that allelopathic crop reduce growth, development and yield of other crops growing simultaneously or subsequently in the field (Batish *et al*., 2001).

Lowest density of *Trianthema portulacastrum* was found in 75 cm apart rows compared with wider row spacing. Narrow row spacing suppressed weeds better than wider spacing. This fact is supported by Fernando *et al*., (2001) who reported that increasing row spacing increased weed density. Lowest numbers of itsit were found in maize intercropped with sorghum. These results are in line with Ahmed *et al*., (1995) who reported that sorghum residues significantly reduced weeds density compared with control.

Lowest biomass of deela was found in 75 cm spacing. Deela biomass increased with increase in row spacing. These results are in line with Sharratt & McWilliams (1998) who reported that weeds biomass decreased with decrease in row spacing. Lowest biomass of deela was found in maize intercropped with sorghum. This lowest biomass yield of deela may be due to allelopathic effect of sorghum. Our results are supported by Bhatti *et al*., (2000) and Nawaz *et al*., (2001) who reported that sorgaab foliar sprays better reduced weeds biomass by 35-65% over control.

Table 9. Mean squares for plant height and stalk yield of maize as affected by the row spacing and allelopathic crops.

Source	Degree of freedom	Mean squares	
		Plant height	Stalk yield
Replication	3	16.9	823177
Row spacing (R)	2	130.1**	2129166**
Error I	6	4.3	79166
Allelopathic crop (A)	4	1732.1**	22588151**
R X A	8	12.2 ns	106705 ns
Error II	36	21.0	447395
Total	**59**		

CV = 2.90%

Table 10. Plant height (cm) of maize as affected by row spacing and allelopathic crops.

Allelopathic crops intercropped in maize	Row spacing (cm)			Mean
	75	85	95	
No weeding	145.7	137.4	135.4	139.5d
Sorghum	157.6	155.2	153.4	155.4c
Sunflower	162.3	159.2	157.4	158.3c
Mungbean	167.0	165.9	164.1	165.7b
No weeding	172.7	170.0	170.1	170.9a
Mean	**161.0a**	**157.5ab**	**156.1b**	

LSD value at p=0.05 for row spacing=2.903, for allelopathic crops=4.146

Means followed by different letters are significantly different from each other at 5% level of probability using LSD test.

Table 11. Stalk yield (kg ha^{-1}) of maize as affected by row spacing and allelopathic crops.

Allelopathic crops intercropped in maize	Row spacing (cm)			Mean
	75	85	95	
No weeding	5437.5	5125.0	5218.7	5260.4d
Sorghum	6312.5	5781.2	5937.5	6010.4c
Sunflower	6593.7	6125.0	6312.5	6343.7c
Mungbean	7812.5	6750.0	6937.5	7166.6b
No weeding	9312.5	8562.5	8687.5	8854.1a
Mean	**7093.7a**	**6468.7b**	**6618.7b**	

LSD value at p=0.05 for row spacing=217.7, for allelopathic crops=553.8

Means followed by different letters are significantly different from each other at 5% level of probability using LSD test.

Row spacing suppressed biomass of *Convolvulus arvensis* compared with wider row spacing. Our results are supported by Weaver *et al*., (1991) who reported that narrow row spacing decreased weeds biomass more effectively than wider spacing. Lowest biomass of *Convolvulus arvensis* was found in maize intercropped with sorghum. The reduction in biomass of weeds may be due to allelopathic effect of sorghum (Leather, 1983).

Lowest biomass of *Trianthema portulacastrum* was found in narrow row spacing of 75 cm compared with wider spacing. Narrow row spacing suppressed weed biomass better than wider row spacing (Singh *et al*., 2003). Lowest biomass of itsit was found in maize intercropped with sorghum. This low biomass production of may be due to the fact that allelopathic crops are the most promising means of weed control by bringing changes in physiological function including respiration, photosynthesis and ion uptake which may reduce growth and overall performance of the target plant (Batish *et al*., 2001; Kohi *et al*., 1997) and may reduce the reliance on synthetic herbicides (Fujii, 2001).

Narrow row spacing of 75 cm produced taller plants compared with wider row spacing. Taller plants in case of narrow row spacing may be due to competition among plants for light and radiation interception (Fernando *et al*., 2001) and providing better condition for the growth (Shah *et al*., 2001). Hand weed control treatment produced taller plants compared with no weed control treatment or intercropped with sorghum or sunflower. Hand weed control may have contributed to the plant height due to enhanced vegetative growth because of increased aeration and nutrients supply (Birkett *et al*., 2001).

Narrow row spacing of 75 cm produced maximum stalk yield compared with wider row spacing. It may be due the fact that optimum row spacing (75 cm) decreased plant competition for available moisture, nutrients and light and increased radiation interception, thus resulted in more dry matter production (Shah *et al*., 2001; Weaver *et al*., 1991; Bullock *et al*., 1988). Hand weed control treatment produced higher stalk yield compared with no weed control and other treatments. It may be due to the fact that weeds if allowed to grow freely may reduce the growth of crop by sharing with the plant for moisture, nutrients and radiation which ultimately result in the low dry matter production of the crop (Sharratt & McWilliam, 1998).

It could be concluded that 75 cm row spacing showed best performance compared with wider row spacing. In case of allelopathic crops maize intercropped with sorghum suppressed weeds density and biomass better than any other crop. Hand weed control may be the best method of weed control subject to the availability of labor.

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