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Response of Sorghum Genotypes to Weed Management under Mediterranean Conditions

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Abstract: A 2-years field study was conducted during the rainy seasons of 1999 and 2000 at Houfa in northern Jordan, to know the performance of two sorghum genotypes (Izra3 and Razini) and their response to monthly hand weeding and 2,4-D application at different growth stages. Izra3 gave significantly higher grain yield of 2800 and 3150-kg ha^{-1} during 1999 and 2000, respectively. Differences in weed number and fresh weight were significant among various treatments in both seasons. In both growing seasons, yield reductions occurred when 2,4-D was applied to sorghum at stage 21 (beginning of tillering, first tiller detectable) and stage 30 (beginning of stem elongation). Hand weeding was more effective than 2,4-D in suppressing weed growth.

Key words: *Sorghum*, 2,4-D, weed control, hand weeding

Introduction

Sorghum (*Sorghum bicolor* L.) is one of the most important annual summer cereal crops grown under dry land conditions. Sorghum is generally used for human food and animal feed and is fourth after wheat, rice and maize in supplying nutrition to humans. About 400 million people in the world depend on grain sorghum as a staple food (Leanord and Martin, 1988). In addition sorghum is used as fodder and stover which are fed to millions of animals providing milk and meat for the nourishment of man. Sorghum thrives in arid and semi-arid areas with less rainfall compared to maize, it grows in areas receiving 350-400 mm of annual rainfall. Many factors are responsible for sorghum yield reduction. Among these are erratic distribution of rainfall, low fertility levels, lack of fertilizers, absence of high- yielding varieties, lack of effective weed control measures and poor knowledge of weed management in sorghum production (Saleh, 1992; Casonova & Solorzano, 1990). Weeds are prime users of soil moisture. Winter annual weeds are of most concern in rainfed farming areas of Jordan because their growth requirements, physiology and seed production are similar to those of sorghum and barley. Both broad-leaved and grassy weeds cause losses in soil moisture and, consequently, crop yields (Abu-Irmailleh, 1982; Klingman & Ashton, 1982).

Weed control in Jordanian rainfed agriculture was limited to mechanical and cultural methods until 20 years ago, but with the advent of herbicides chemical weed control became possible and resulted in better weed control and increased crop yields (Tamimi, 1981; Duwayri & Saghir, 1983). Hand weeding, which was the main mechanical method for weed control was abandoned because it was no longer economical. Chemical weed control of broad-leaved weeds in Jordan, dates back to the early 1970s. The herbicide 2,4-D was the first to be introduced into Jordan rainfed areas for the control of broad leaved weeds (Goetze, 1976; Qasim, 1982), and is still used in cereals. Early research with winter wheat cultivars identified the 2-leaf stage (Olsen *et al.*, 1951; Klingman, 1953) and more recently Robinson & Fenster (1973) as the safest time for application of this herbicide. Crop safety of 2,4-D on the newer cultivars grown in Jordan has not been evaluated and growers have reported injury to sorghum crops when recommended herbicides have been used.

Phenoxy herbicides have been used for broad-leaved weed control in wheat since the late 1940s, however misapplication can reduce the yield (Klingman and Ashton, 1982; Swan 1975). Wheat is susceptible to phenoxy herbicide injury from emergence to the four leaf stage and from jointing to the soft dough stage of growth (Coupland, 1950; Friesen, 1950; Martin *et al.*, 1989; Martin *et al.*, 1990). Phenoxy herbicide applied at these stages can reduce plant height, delay maturity, and reduce grain yield due to inhibition of cell division and growth in the meristematic regions (Klingman and Ashton, 1982). Plants treated with 2,4-D often exhibit malformed leaves, stems, and roots as 2,4-D affects plant metabolism by stimulating nucleic and protein syntheses which affects the activity of enzymes, respiration, and cell division (EPA, 1988). Often cells in the phloem of treated plants are crushed or plugged, interfering with normal food transport (Mullison, 1987) which can leave parts of the plant malnourished or possibly lead to death. Weed problems in wheat, and weed response to commonly used wheat herbicide is well known. There is, however little information on sorghum tolerance of herbicides. The objective of this research was to study the performance of two sorghum genotypes and their response to hand weeding and 2,4-D applied at different growth stages under semi-arid conditions.

Materials and Methods

Field experiments were conducted at Houfa in northern Jordan during the two growing seasons of 1999 and 2000. The location has a Mediterranean type climate of mild rainy winters and dry hot summers. The experimental field received granular fertilizer DAP (diammonium phosphate 18 % N and 46 % P_2O_5) at a rate of 100 kg ha^{-1} which was applied and mixed with soil prior to planting. Split plot designs with three replications were used in both years. Sorghum seeds from the two genotypes Izra3, and Razini were allocated randomly to 2.4 m x 25.2-m plots. The seeding was carried out on 10th, Jan. 1999 and 13th, Jan. 2000 at a planting density of 62500 plants ha^{-1}. Herbicide and hand weeding treatments were randomly assigned to each genotype plot, representing the sub-plot treatments. In each sub-plot, the seeds were planted in 6 rows 2.4-m long and spaced 40 cm apart. The dominant broad leaved weed species were *Cardaria draba* L., *Diplotaxis erucoides* L., *Molucella laevis* L., *and Brasica nigra* L. The dominant grass weed was *Hordeum murinum* L.

Weed treatments were weed check (untreated), hand – weeding (practiced monthly during the growing season) and 2,4-D (2,4-dichlorophenoxy acetic acid) which was applied at a rate of 480 g ha^{-1} (a. I), to the sorghum genotypes at two of growth stages. The herbicides were applied by a mounted sprayer equipped with a fan-type nozzle. Plots were evaluated visually on a 0 to 100 scale where 0 = no injury and 100 = plant death to estimate sorghum injury 21 days after the treatment. The sorghum growth stages were identified using the BBCH code. The sorghum growth stages and herbicide application dates were stage 21 (beginning of tillering, first tiller detectable), March, 27, 1999, and March, 23, 2000, and stage 30 (beginning of stem elongation), May, 8, 1999 and May, 9, 2000. The weather data at application time and after application during both growing seasons are presented in Table 1. Each year include grain yield (kg ha^{-1}), panicles plant^{-1}, grains panicle^{-1}, plant height (cm), panicle length (cm), and days to 50% heading were recorded. Before harvest, weed number and fresh above ground biomass were determined in four 0.25 of 0.25 of m^{2} random quadrates per plot. The weed control efficiency (WCE) was calculated by using the following formula of Singh *et al.* (2000).

$$\frac{\text{Dry matter of weeds in unweeded plot} - \text{Dry matter of weed in treatment}}{\text{Dry matter of weeds in unweeded plot}} \times 100$$

Sorghum plants were harvested at maturity on July 10, and July 20, in 1999 and 2000 growing, respectively. The plants of one m^{2}

quadrate were clipped at 10 cm above the soil surface by hand sickles from the three central rows of each plots. The MSTAT-C program was used for statistical analysis. Data for each trait were analyzed for a randomized complete block design (RCBD) with split plot arrangement according to procedure outlined by Steel and Torrie (1980). Comparisons between means were made using least significant differences (LSD) at 0.05 probability level.

Results and Discussion

The 1999-2000 growing season was cooler and wetter than 1998-1999 with a seasonal precipitation of 184.8 mm and 342.6 mm, in each growing season, respectively. The annual variation of rainfall in Jordan is very high, especially in areas of low rainfall. The high inter-annual variability of rainfall and its erratic distribution are major reasons for low sorghum yields. More than 78.2 % of the seasonal precipitation in 1999-2000 season was concentrated in January and February, while in the 1998-1999 season it was only 60.3 % in these months (Table 1). In both growing seasons, stage 21 (beginning of tillering, first tiller detectable) and stage 30 (beginning of stem elongation), were susceptible to 2,4-D injury at (stage 30). More visible injury was caused at stage 21 treatment. The results are in accordance with those of Martin *et al.* (1990), Klingman and Ashton (1982).

Significant differences ($P \leq 0.05$) in grain yield were recorded between the genotypes studied during both growing seasons (Table 3). In both growing seasons, the Izra3 gave the highest grain yields of 2800 and 3150 kg ha^{-1}; respectively, and Razini gave the lowest grain yields of 2345 and 2775 kg ha^{-1}; respectively. The variation is related to the differences in genetic yield potential among genotypes (Saleh, 1992).

Table 1: Average minimum and maximum monthly temperature (°C) and monthly rainfall (mm) distribution during 1998-1999 and 1999-2000.

Month	Minimum (°C) temperature	Maximum (°C)temperature	Rainfall (mm)
Sept.98	12.1	18.0	-
Oct. 98	14.1	18.0	1.3
Nov. 98	8.0	13.1	0.4
Dec. 98	9.0	13.1	14.1
Jan. 99	6.0	14.0	69.2
Feb. 99	6.0	26.0	42.2
Mar 99	7.0	28.0	49.2
Apr. 99	17.0	30.1	8.4
May. 99	17.1	29.8	-
Total			184.8
Sept.99	10.1	14.0	-
Oct. 99	12.1	14.0	-
Nov. 99	6.0	12.1	14.9
Dec. 99	8.0	13.1	20.5
Jan. 2000	5.0	17.0	213.8
Feb. 2000	5.0	23.0	54.2
Mar 2000 5.0		25.0	38.9
Apr. 2000	6.0	26.1	0.4
May. 2000	7.0	28.1	-
Total			342.6

Table 2: Sorghum injury as affected by genotypes and 2,4-D treatments.

Treatments	Genotypes			
	Izra3		Razini	
	1998-1999	1999-2000	1998-1999	1999-2000
Control	0	0	0	0
Hand-weeding	0	0	0	0
2,4-D at stage 21	17	12	19	13
2,4-D at stage 30	30	28	32	28

Data not analyzed statistically.

In both growing seasons, grain yield was affected by weed control methods and hand weeding provided better weed control and this was reflected in higher sorghum yields in both seasons. The increase in grain yield with the hand weeding was mainly due to their effective control of weeds by reducing dry matter of weeds and weed intensity which resulted in more panicles plant^{-1} and grains panicle^{-1} (Table 3) and finally higher grain yield. The effect of weed removal on sorghum yield was more obvious in the second growing season, where sorghum yield in weedy plots was 31.7 % less than hand weeded, compared to 23.4 % reduction in the first growing season. The reduction in sorghum yield due to weed interference was greater in the second season that was characterized by better weather conditions, which allowed weeds to grow and suppress the weak and slow growing sorghum plants. Significant differences in panicles plant^{-1} and grains panicle^{-1} due to weed interference were observed in both growing seasons (Table 3). Weedy plots had fewer panicles plant^{-1} and grains panicle^{-1} when compared to hand weeded plots. The growth stage by 2,4-D interaction was not significant when sorghum yield data were analyzed. In both growing seasons, 2,4-D applied at stage 21 decreased the sorghum yield 13.9 and 7.1 % respectively. The lowest grain yield was recorded when 2,4-D was applied at growth stage 30, reducing sorghum yields by 25.6 % and 16.1 % ; respectively. Sorghum yield reductions with 2,4-D was related closely to reductions in number of grains panicle^{-1} and panicles plant^{-1} (Table 3). These results are in agreement with earlier studies reporting by Turk and Tawaha (2001).

Significant difference ($P \leq 0.05$) in plant height were recorded between genotypes studied during both growing seasons (Table 4). In both growing seasons, the Izra3 genotype gave significantly the highest plant height of 142.5 and 146.5 cm; respectively. Plant heights and panicle length were markedly increased in weed-free plots compared with other treatments (Table 4). The results of this study add support to previous studies by Turk and Tawaha (2001).

In comparison, 2,4-D reduced plant height and panicle length and the lowest plant heights were recorded with 2,4-D applied at growth stage 21 in both years (Table 3). The results of this study are in agreement with those obtained by Klingman and Ashton (1982) who found that 2,4-D applications can reduced the plant height. This may be due to the fact that 2,4-D and other auxin –type herbicides inhibit meristematic cell division and growth

Table 3 Yield and yield components for two sorghum genotypes as affected by hand- weeding and 2,4-D application at two growth stages

Genotypes	Grain yields (kg ha^{-1}) 1999	2000	Panicles plant^{-1} 1999	2000	Grains panicle^{-1} 1999	2000
Izra3	2800.0 a	3150.0 a	2.8 a	3.5 a	1214.8a	1279.8 a
Razini	2345.0 b	2775.0 b	1.8 b	2.5 b	1100.3 b	1139.0 b
LSD (0.05)	230.0	310.0	0.7	0.9	98.0	121.0
Treatments						
Control	2620.0 b	2800.0 b	2.5 b	3.5 b	1160.5 b	1244.5 b
Hand-weeding	3420.0 a	4100.0 a	3.5 a	4.0 a	1486.5 a	1400.0 a
2,4-D at stage 21	2300.0 c	2600.0 c	1.5 c	2.5 c	1020.5 c	1198.0 c
2,4-D at stage 30	1950.0 d	2350.0 d	1.5 c	2.0 d	962.5 d	995.0 d
LSD (0.05)	183.0	240.0	0.6	0.4	55.0	45.0
G x Trt	NS	NS	NS	NS	NS	NS

(*) Means in each column followed by same letters are not significantly different according to LSD ($P \leq 0.05$).

Table 4: Phenological traits for two sorghum genotypes as affected by hand- weeding and 2,4-D application at two growth stages.

	Plant height (cm)		Panicle length (cm)		Days to 50 % heading	
Genotypes	1999	2000	1999	2000	1999	2000
Izra3	142.5 a	146.5 a	21.5 a	22.8 a	66.5 a	71.5 a
Razini	137.5 b	140.3 b	18.8 b	20.3 b	66.5 a	71.8 a
LSD (0.05)	3.5	5.1	2.1	2.4	NS	NS
Treatments						
Control	142.5 b	146.0 b	21.5 b	23.5 b	66.0 b	70.5 b
Hand-weeding	147.5 a	150.0 a	24.0 a	26.0 a	64.0 a	68.0 a
2,4-D at stage 21	132.5 d	135.0 d	19.0 c	19.5 c	68.0 c	74.0 c
2,4-D at stage 30	137.5 c	142.5 c	16.0 d	17.0 d	68.0 c	74.0 c
LSD (0.05)	3.1	3.2	1.6	2.1	1.7	1.5
G x Trt	NS	NS	NS	NS	NS	NS

(*) Means in each column followed by same letters are not significantly different according to LSD ($P \leq 0.05$).

Table 5: Number and weight of weeds for two sorghum genotypes as affected by hand- weeding and 2, 4-D application at two growth stages.

	Number of weeds		Weight of weeds (g m^{-2})		*Weed control efficiency (%)		*Weed control efficiency
Genotypes	1999	2000	1999	2000	1999	2000	(%) Mean
Izra3	9.5 a	12.8 a	152.0 a	218.8 a	-	-	-
Razini	10.3 a	13.8 a	160.0 a	229.3 a	-	-	-
LSD (0.05)	NS	NS	NS	NS	-	-	-
Treatments							
Control	20.0 a	23.5 a	320.0 a	580.0 a	-	-	-
Hand-weeding	2.5 d	2.5 d	40.0 d	36.0 d	87.5	93.4	90.5
2,4-D at stage 21	6.5 c	12.5 c	104 .0 c	100.0 c	67.5	82.8	75.2
2,4-D at stage 30	10.5 b	14.5 b	160.0 b	180.0 b	50.0	69.0	59.5
LSD (0.05)	4.0	3.1	55.0	45.5	-	-	-
G x Trt	NS	NS	NS	NS	-	-	-

(*) Means in each column followed by same letters are not significantly different according to LSD ($P \leq 0.05$). * Data statistically not analyzed.

(Turk and Tawaha, 2001). In both growing seasons, no significant differences in days to 50% heading were recorded betwveen the genotypes studied. Days to 50% heading was the same in both genotypes when 2,4-D was sprayed in both growing seasons irrespective of time of applications.

Differences in weed number and fresh weights were significant among the various treatments in both seasons (Table 5). Hand weeding reduced the weed number and fresh weight better than control treatments. In addition, hand- weeding was more effective than 2,4-D in suppressing weed growth. Averaged over two years, the weed control efficiency ranged from 59.5 to 90.5%. Maximum weed control efficiency of 90.5 was recorded with the hand weeding, whereas it was 75.2 with to 2,4- D at stage 21. Minimum weed control efficiency was recorded with 2,4-D applied at stage 30 during both growing seasons. Turk and Tawaha (2001) support these findings.

In conclusion, using suitable high yielding genotypes which can stand moisture stress or erratic rainfall during the growing period is one of the major ways of improving sorghum yields. Weeds and 2,4-D reduce sorghum yields. The magnitude of reduction was greater from 2,4-D than from weed interference. Hand weeding, proved to be superior when compared to 2,4-D, irrespective to stage of application, under the conditions that prevailed in this study. In both growing seasons 2,4-D applied at stage 21 and stage were associated with yield reductions closely related to reduction in panicles $plant^{-1}$ and grains $panicle^{-1}$. Based in this study, 2,4-D application is not recommended in hot dry areas because of its negative effect on yield and yield components. Farmers are encouraged to practice hand weeding, which gave best yields in both seasons.

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