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Yield Response of Sorghum (*Sorghum bicolor* L.) to Manure Supplemented with Phosphate Fertilizer Under Semi-arid Mediterranean Conditions

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ABSTRACT

Response of two sorghum cultivars namely Izra-7 and Razini to manure and phosphate fertilizer was studied in factorial arrangement in two separate field experiments on calcareous soil at Jordan University of Science and Technology campus (JUST). Increased yields of both cultivars was obtained by integrated application of manure and P, which was a consequence of high harvest index, grain number and panicle length coupled with more total dry matter production. Grain and biological yield of Izra-7 responded to lowest combinations of manure and fertilizer P when compared to Razini that responded significantly up to the highest combination rates. Regression analysis showed linear effects of both manure and P on grain and biological yields. Increased residual P content of the soil after sorghum harvest was evidenced with much more contribution from manure compared to P applied. Overall, manure application at highest rate increased grain yield and other yield component; however, its effects were more pronounced when applied with mineral P. The benefit of integrating manure with Phosphate fertilizer was evident.

Key Words: *Sorghum bicolor*; Phosphorus; Fertilizer; Manure

INTRODUCTION

The major constraint to productivity of crops in the semi arid regions is inadequate, unreliable and poorly distributed rainfall. The major dryland agricultural areas of Jordan receive an annual rainfall of 250-600 mm, which is erratic and highly variable between seasons (Jaradat, 1988). In addition, low crop productivity under rain fed conditions of the country is attributed, in part, to the low soil fertility (N & P). However, there is limited use of mineral and organic fertilizers on crops (Khattari & Tell, 1988) owing to limited resources and the risk associated with fertilization in an environment of low and uncertain rainfall. Also, plant responses and utilization of P is extremely low due to the high immobility and fixation in the calcareous soil characterized with high pH and low moisture (Khattari & Tell, 1988). This requires large input of P to meet the needs of crops for optimum productivity. Under such circumstances and continuous decreases in organic matter and nutrient content of the soils, the importance of integrated use of organic and inorganic nutrient sources has been indicated (Misra & Maheshwari, 1988; Hegde, 1996; Damodar Reddy *et al*., 1999). Organic sources such as animal manure can be an effective source of major nutrients (N, P, & K) when applied at optimum rates and can influence the temporal dynamics of nutrient availability (Paul & Beauchamp, 1993), increase water use efficiency of crops (Carter *et al*., 1992) decrease soil P fixation and enhances P availability in the soils (Iyamuremye & Dick, 1996) through its effect on physical and chemical properties of the soil. Despite all this, a complement of mineral fertilizer is usually required for a good nutrient balance. There is possibility to use livestock manure as an alternative nutrient source alone or in combination with inorganic fertilizers for food and feed production in Jordan, as agriculture is primarily based on dryland cereals integrated with livestock production. However, little information is available. The objective of this work was, therefore, to study the response of two sorghum cultivars to manure and phosphate fertilizer under irrigated semi-arid Mediterranean conditions of Jordan.

MATERIALS AND METHODS

The field experiments were conducted at main research station of the Jordan University of Science and Technology (JUST) campus in Northern Jordan during the 2000-2001 summer growing seasons. The location has Mediterranean climate of mild and wet winter and hot and dry summer. The soil is fine-loamy, thermic, calcic paleargid (Khresat *et al*., 1998) with N-NH4 (5.25 mg kg^{-1}), N-NO3 (16.78 mg kg^{-1}), available P (3.33 mg kg^{-1}), Organic matter (0.79%) and pH of 7.93. Twelve treatment combinations consisting of 2 factors, viz. sheep manure at 4 levels (0, 10, 20, & 30, t ha^{-1}) and phosphorus at 3 levels (0, 28 & 56 kg P2O5 ha^{-1}) was tried in factorial randomized complete block design, with three replicates. Sorghum cultivars used were (i) Razini, tall and early maturing (ii) Izra-7, short and intermediate in maturity. Each sorghum cultivar was tested in a separate trial. Each plot consists of five rows 2.4 m long and 0.4 m apart. Two seeds per hole were sown and being thinned to one plant per hole two weeks after emergence. Sheep manure was collected two months prior to application, and was manually incorporated to the upper 10-15 cm of the soil a week before sorghum planting. The composition of manure used was-moisture content (10.65%), organic matter (57%), total nitrogen (2.44%), available P (0.35%) and pH of 8.1. Fertilizer P as per treatment was band applied to the side of the seeds in the rows at the time of sowing. Plots were weeded twice at 30 and 45 days after emergence. Insect pests were controlled using Dimethoate 40-D w/v. The plots were irrigated (drip) one or two times every week depending on growth stages of the crop to avoid water stress.

At harvest, the plants were harvested by hand and the following parameters were taken-biomass yield (t ha^{-1}), grain yield (t ha^{-1}), panicle length (cm), harvest index, number of grains per panicles, and 1000 grains weight (g). Also, three random soil cores from each plot were taken from the 0-15 cm depth after the harvest of the crop. Soil cores were mixed, air-dried and ground to pass a 2-mm sieve. The samples were analyzed for available P following procedures described by (Olsen *et al*., 1954). Finally, data were statistically analyzed using the general linear model procedure of the SAS program (SAS Inst., 1990). Wherever appropriate, the treatment means were compared at 5% level of significance using Fisher's protected Least Significant Difference (LSD) test. The association between grain yield and other quantitative parameters were analyzed and using the stepwise method a multiple linear regression was utilized to model significant manure and fertilizer P effects on selected dependent variable.

RESULTS AND DISCUSSION

Yield and yield attributes. The results revealed significant main effects of P and manure and their interaction on total crop biomass and grain yield for both cultivars, while only the main effects are significant for panicle length, number of grains per panicle and 1000-grain weight (Tables I & IV).

Biomass yields of both varieties generally increased with increase in manure applied. The response equation fitted shown in Table III also reveals significant and linear response to manure and P and their combination as well for Izra-7, illustrating the important role both manure and P play with regard to high total biomass yield production, with more contribution being due to manure. Especially, the effects of manure on total biomass yield of variety Izra-7 was pronounced with phosphorus application regardless of the rates and as a consequence the lowest rate of manure gave yield comparable to the higher rates of manure at the same or different rates of P application. However, the slope of the total biomass yields response to combinations decreased with increase in rates of combinations. Among the treatments, higher biomass yield (26.08 t/ha for Razini & 25.33 t/ha for Izra-7) were obtained by combined application of 30 t/ha manure and 56 kg P2O5 ha^{-1} which was 53.3 and 60% higher than the control, respectively (Table I). It is important to note that the effect of manure revealed on Izra-7 was some what different from the one observed for Razini, in that, Izra-7 responded to combinations of the lowest rate of manure and gave yield comparable to the one observed on higher rates of P and manure combinations. This might be related to genotypic differences in nutrient acquisition efficiency. The results observed in this study is obvious as the contributions of head (panicle) to total biomass yield was greater in fertilized plots compared to unfertilized plots in which the stem contributed much to the total biomass yield. This is in conformity with the findings of Roy and Wright (1973), where the contribution of head to biological yield increased when nitrogen and phosphorus were applied.

Grain yield was regressed against manure and P fertilizer rate at planting for both cultivars. The best-fit regression equations included the same variables for the cultivars and had R2 values of 0.74 for Razini and 0.82 for Izra-7 (Table III). In both cases, the variable contributing the most to the estimation of grain yield was manure rate, although fertilizer P rate also made a significant contribution to accounting for the variability in grain yield. The grain yield response to both manure and P increased almost with increase in application rates of either alone. Besides, the

Table I. Effects of manure and fertilizer P on total biomass and grain yield of Sorghum cv. Razini and Izra grown at JUST campus

P_2O_5 rates (Kg ha^{-1})	Manure rates (t ha^{-1})									
	0	10	20	30	Mean	0	10	20	30	Mean
			Cultivar Razini					Cultivar Izra		
					Biomass yield (t ha^{-1})					
0	17.01	21.55	22.84	24.15	21.41	15.83	20.46	22.31	24.70	20.83
28	21.51	22.71	22.66	25.34	23.06	21.47	22.61	23.95	24.28	23.08
56	23.55	22.55	24.39	26.08	24.14	23.25	24.21	23.73	25.33	24.13
Mean	20.72	22.27	23.30	25.19		20.19	22.43	23.33	24.77	
LSD (P ≤ 0.05)	Manure = 1.41; Phosphorus = 1.22 Interaction = 2.44					Manure = 1.69; Phosphorus = 1.46; Interaction = 2.93				
					Grain yield (t ha^{-1})					
0	5.14	7.27	7.70	8.42	7.14	4.70	7.08	8.33	9.27	7.35
28	7.33	8.07	7.97	9.08	8.12	7.60	8.56	8.91	9.47	8.64
56	8.27	8.26	9.11	9.17	8.70	9.13	9.30	9.25	9.35	9.26
Mean	6.91	7.87	8.26	8.89		7.15	8.31	8.83	9.37	
LSD (P ≤ 0.05)	Manure = 0.48; Phosphorus = 0.41; Interaction = 0.83					Manure = 0.58; Phosphorus = 0.50; Interaction = 1.01				

effect of manure at the highest rate was the same regardless of P fertilization indicating higher nutrient availability at this rate compared to lower rates in which additive nature was revealed. This could be due to the fact that manure application even at lower rates can form complex with P sorption sites, mobilize native soil P (Iyamuremye & Dick, 1996) and promote P availability leading to better crop growth. On top of this, the soils contained little available P (3.33-mg kg^{-1}), thus such responses can be expected.

The highest yields (9.17 t/ha for Razini & 9.47 t/ha for Izra-7) were obtained when 30t/ha manure was applied along with 56 kg P2O5 ha^{-1} and 28 kg P2O5 ha^{-1}, which is 78 and 101% higher when compared with control (no P & manure), respectively (Table I). Sharma *et al.* (1988) found no significant increase in grain yield with addition of 110 kg P2O5 ha^{-1}, however, its combined application with 3.5 t ha^{-1} farmyard manure increased grain yield to a marked level. Overall, the significant increase in grain yield observed in both cultivars with combined applications of manure and P was generally related to the improvements in biological yield and yield components resulted from good vegetative crop growth by adequate supply of the essential (N, P) nutrient elements. This is clearly shown in Table II where the variation in yield observed was mainly proportional to the variation in biological yield produced (proportion of variability = 80% and 86% for Izra-7 and Razini, respectively, P<0.001). This finding supports the results of Muchow (1990) who found significant positive relationship between grain yield and biological yield at maturity over entire yield range in his study. In terms of yield components, variation in grain yield was accounted for by variation in number of grains, similar to the frequent observations of Muchow (1988, 1990), in panicle length and also by seed weight in Izra-7.

The sorghum cultivars developed longer panicles with more number of grains with application of manure at higher rates (20 & 30 t ha^{-1}), being no significant difference observed between the rates (Tables IV); whereas, larger panicle with higher grain weight was produced in response to phosphorus fertilization. It is in accord with the reports of Lal and Mohammad (2000) and Elkased and Nandi (1987). The two sorghum cultivars responded similarly to P application. The effect observed on number of grains through manuring was presumably due to more availability of most vital nutrients (N, P) during the growth period. Nitrogen availability was found to induce formation of proteins and enzymes in adequate quantities, which could act on the metabolites in the leaves and stem enhancing their conversion, transportation and accumulation in the grains (Krishnasamy & Ramaswamy, 1986); whereas, an increase in grain number to phosphorus applied was observed only for the cultivar Izra-7. The effect of P fertilizer in increasing grain number is parallel to its effect on larger panicle production. Govil and Prasad (1972) reported an increase in grain number per panicle with P application. Despite significant influence of P on panicle length of Razini, the number of grains per panicle was not influenced. The findings lend supports to the report of Lal and Mohammad (2000).

Table II. Coefficients of determination (R^2) for total biomass yield at maturity, panicle length, and number of grains per panicle, thousand grain weight and harvest index component contributing to grain yield of Sorghum cultivars

Cultivars	Parameters				
	BY	PNL	GNR	GW	HI
Razini	0.86***	0.52***	0.34***	0.06NS	0.42***
Izra-7	0.80***	0.56***	0.50***	0.24**	0.54***

, * Significant at 0.01 and 0.001 levels, respectively; NS indicates not significant; BY = total biomass yield, PNL = panicle length, GN= grain number, GW= grain weight and HI= harvest index.

Table III. Best-fit regression models of grain and total biomass yield of Sorghum cultivars as a function of manure and P fertilizer at planting

Cultivars	R^2	SE	N	Models
Razini				
	0.74	0.625	36	Y1 = 5.753 + 0.0966(M)*** + 0.0214(P)*** 0.0006 (M X P)**
	0.50	2.058	36	Y2 = 19.302 + 0.146(M)*** + 0.0227(P)**
Izra-7				
	0.82	0.72	36	Y1 = 5.304 + 0.144(M)*** + 0.0339(P)*** 0.0012(M X P) ***.
	0.72	1.593	36	Y2 = 16.99 + 0.261(M)*** + 0.057(P)*** – 0.0019(M X P)***

, * Significant at 0.01 and 0.001 levels, respectively; N = number of means; Y1 = Grain yield; Y2 = Biomass yield; M = manure, t ha^{-1}; P = P fertilizer rate, Kg P_2O_5 ha^{-1}

Table IV. Effects of manure and fertilizer P on fertile tillers per plant, panicle length, grains per main panicle and thousand- grain weight of Sorghum grown at JUST

	Razini			Izra-7		
Treatments	Panicle length	Grains/ panicle	Thousand grain weight	Panicle length	Grains/ panicle	Thousand grain weight
P_2O_5 rates (Kg ha^{-1})						
0	26.92	2638.5	32.17	28.55	3458.17	28.28
28	27.57	2803.9	32.80	29.73	3624.17	29.71
56	27.77	2795.3	33.77	29.72	3650.33	29.89
LSD ($P \leq 0.05$)	0.59	NS	1.05	0.74	161.66	0.73
Manure rates (t ha^{-1})						
0	26.42	2574.0	32.99	28.43	3361.56	28.69
10	26.98	2708.7	33.49	29.10	3566.00	29.63
20	27.93	2805.2	32.67	29.62	3631.78	29.56
30	28.33	2895.4	32.49	30.18	3750.89	29.30
LSD ($P \leq 0.05$)	0.68	207.85	NS	0.86	186.67	NS

NS, not significant

The non-significant manure effects obtained in this study is similar to results of Muchow (1988) who found similar grain size development at all levels of applied N in sorghum. While, the varieties responded significantly to the application of P. Govil and Prasad (1972) observed significant increase in thousand-grain weight due to the addition of 60 kg P_2O_5 ha^{-1}. It is also in agreement with those of Lal and Mohammad (2000) who found significant increase in grain weight with increase in P rates to 80 kg P_2O_5 ha^{-1} but no increase with further P rates. When the two cultivars are compared, less grain weight was obtained with Izra-7 than Razini that may be related to more number of grains per panicles in the former. It is generally accepted that an increase in number of grains is accompanied by a decrease in the weight of individual grain and vice versa, as the maximum yield that can be achieved has a ceiling that cannot be surpassed.

Post harvest soil phosphorus. Soil P concentrations following sorghum harvest differed significantly among the plots in response to P fertilizer and manure application. Fertilizer phosphorus application at both rates increased residual phosphorus contents of the soil after harvest of sorghum razini while only highest rate of applied P had increased soil P after harvest of Izra-7 (Fig. 1 & 2). Comparison of the pre-plant soil P with the soil P concentrations following cropping indicated that the effect of phosphorus application alone on residual soil P was not substantially high and generally very low to support good plant growth. This is because on soils with high fixing capacity (calcareous soils) fertilizer P applied was rapidly converted to relatively insoluble forms, followed by a trend of decreasing soil test P levels back toward a relatively stable equilibrium value with time (Yang & Jacobsen, 1990). The result was similar to the findings of Hibberd *et al.* (1991). On the other hand, post-harvest soil P concentrations increased significantly with increase in rates of manure application. The highest residual soil P concentrations of 21.43 and 20.92 mg kg^{-1} after harvest of Razini and Izra-7, respectively, were obtained on plots receiving the highest rate of manure (30 t ha^{-1}). As shown, the trend of available soil P on soils planted with both sorghum cultivars in response to manure application were similar. This was also shown in the fitted regression models indicated in Table V. The model illustrates the significance of manure application with respect to accounting for residual available soil P, and the response was linear through out the entire range of manure levels. Though the effect of applied P was low as compared to manure as shown in the model, still it had an impact particularly at highest rate.

The increase in residual P contents in the soil by the application of fertilizer P as well as the more pronounced

Fig. 1. Surface soil (0-15 cm) bicarbonate-extractable soil P concentrations following Sorghum (Razini) harvest, as affected by phosphorus (Kg P_2O_5 ha^{-1}) and manure (t ha^{-1}) application during planting. Means with different letters are significantly different ($P \leq 0.05$) according to Fisher's protected Least Significant Difference test

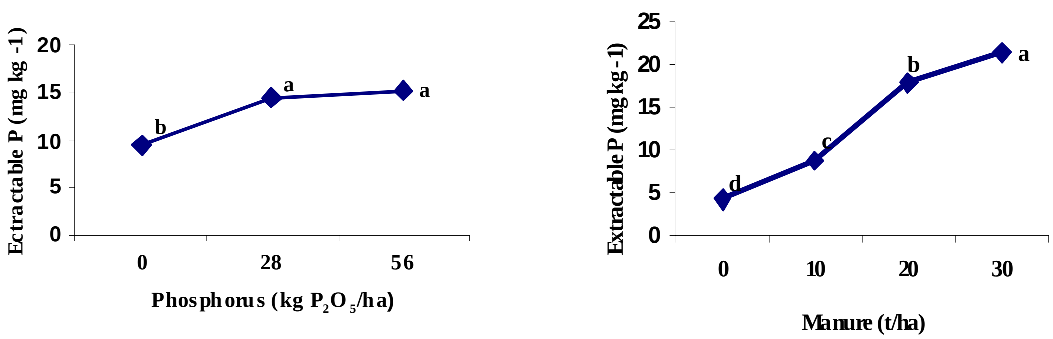

Fig. 2. Surface soil (0-15 cm) bicarbonate-extractable soil P concentrations following Sorghum (Izra-7) harvest, as affected by phosphorus (Kg P_2O_5 ha^{-1}) and manure (t ha^{-1}) application during planting. Means with different letters are significantly different ($P \leq 0.05$) according to Fisher's protected Least Significant Difference test

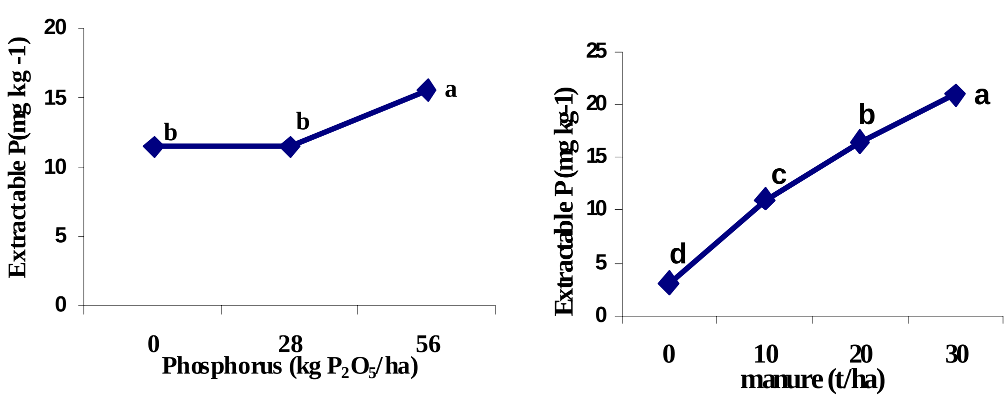

Table V. Fitted regression models of residual available soil P as a function of manure and P fertilizer applied at planting to two Sorghum cultivars.

Cultivars	R^2	N	Models ‡
Razini	0.84	36	Y=3.93+0.445(manure) + 0.002716(manure X P)
Izra-7	0.85	36	Y = 2.34 + 0.561(manure) + 0.000297(P)^2

‡ Y= available soil P, mg kg^{-1}; P = P fertilizer rate, kg P_2O_5 ha^{-1}; Manure = manure rate, t ha^{-1}

increase where sheep manure was used either alone or in combination with inorganic fertilizer was in line with the reports of Dormaar *et al*. (1988) and Chaudhry *et al*. (1999). Organic manures are known to decrease P adsorption/fixation and enhance P availability in P fixing soils (Iyamuremye & Dick, 1996). Thus, the decomposition products of organic manure in the soil may have arrested the fixation/adsorption thereby extending P availability (Sharma *et al*., 1988; Iyamuremye *et al*., 1996) and in turn improving utilization of the applied P. It was also revealed that manure application contributed much too high available residual soil P than fertilizer P depicting its fertility potentials for the next consecutive seasons besides its immediate effects. Above all, P application in combination with organic manures not only improve fertility status but are also potential for restoring (Khalid *et al*., 1999) and maintaining productivity of a soil (Hegde, 1996; Damodar Reddy *et al*., 1999), which could otherwise be impossible even with balanced application of inorganic fertilizers alone or by relying on any other single measure for maintaining fertility (Guar, 1992).

CONCLUSIONS

Our data demonstrated that sorghum yields for both cultivars can be increased in North part of Jordan by integrated application of manure and P, which was a consequence of high harvest index, grain number and panicle length coupled with more total dry matter production.

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