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EFFECT OF PHOSPHORUS AND ZINC FERTILIZATION ON GROWTH AND GROWTH INDICES OF FODDER SORGHUM (*SORGHUM BICOLOR* L.)

BHANUPRAKASH N.[1], J. S. YADAV[2], ANIL KUMAR[3], SATPAL[4], AKSHIT[1], SUSHIL KUMAR[1]* AND SURENDER KUMAR[1]

[1]Department of Agronomy, CCS Haryana Agricultural University, Hisar-125 004 (Haryana), India
[2]Regional Research Station, Bawal, CCS Haryana Agricultural University
[3]Bajra Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar-125 004 (Haryana), India
[4]Forage Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar-125 004 (Haryana), India
(e-mail : puniasushil22@gmail.com)

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SUMMARY

The effect of phosphate and zinc fertilization on fodder sorghum growth and growth indicators was investigated in this study. The experiment was set up in a split-plot design with four phosphorus levels in the main plot (T_1- Control, T_2- 7.5 kg P_2O_5 ha^{-1}, T_3- 15 kg P_2O_5 ha^{-1}, and T_4- 22.5 kg P_2O_5 ha^{-1}), and four zinc levels as sub-plot treatments (S_1- Control, S_2- 0.50 percent foliar spray of $ZnSO_4$ at 20-25 DAS, S_3- 0.75 percent foliar spray of Zn. At all growth phases, 22.5 kg P_2O_5 ha^{-1} (P_4) significantly increased the number of leaves and leaf area index as compared to 7.5 kg P_2O_5 ha^{-1} (P_2), 15 kg P_2O_5 ha^{-1}, and control treatments. Among different Zn treatments, the number of leaves and leaf area index was significantly higher with the application of 25 kg $ZnSO_4$ ha^{-1} over foliar application of $ZnSO_4$ *i.e.* 0.5 %, 0.75 %, and control, at all growth stages whereas foliar treatments were at par with each other at 40 DAS, 60 DAS and at the cutting stage. With the application of 25 kg $ZnSO_4$ ha^{-1}, significantly greater LAI, LAD, CGR, RGR, and NAR were recorded compared to other zinc levels.

Key words : Fodder sorghum, phosphorus, zinc, growth indices, LAI, CGR, NAR

Sorghum [*Sorghum bicolor* (L.) Moench] is the widely grown cereal forage crop of the country (2.6 m ha) and single cut sorghums account for 23.1% of this. Short duration (60 to 80 days) with its ability to produce high biomass (Satpal *et al.,* 2020) under wide edapho-climatic situations across the country including Andaman & Nicobar Islands (Gangaiah and Kundu, 2020) and saline conditions (Devi *et al.,* 2021) during *kharif* season. Selection of location specific genotype along with optimum application of required primary, secondary and micronutrients is needed to realize the potential of fodder sorghum.

Phosphorus is the second most lacking plant nutrient after nitrogen (Munir *et al*., 2004). The use of phosphorus fertilizer is critical since it directly affects the amount and quality of fodder production. Plant height, stem diameter, number of leaves per plant, leaf area per plant, and fodder output all improved as phosphorus application progressed (Khalid *et al*., 2003).

Zinc is a necessary micronutrient that functions as a cofactor for over 300 enzymes and proteins involved in cell division, nucleic acid metabolism, and protein synthesis. In comparison to the national average, zinc deficiency in Haryana soils ranges between 5 and 15% (average 15.3%). (Shukla *et al*., 2015). Zinc deficiency in the soil causes low feed output and quality, as well as inadequate zinc absorption. Because zinc is a key mineral in animal nutrition, a deficit in animals may be corrected by applying zinc at the right rate to the soil. All other plant nutrients impact zinc availability in soils, as well as its absorption and transport in plants. Zinc has an antagonistic relationship with phosphorus, which is influenced by soil physicochemical parameters.

For unlocking the yield potential of crops, advancement in crop production technology is the key component. Fodder, as a set of crops, varies from food and commercial crops in various ways, and its production principles and techniques change correspondingly. Given the foregoing, it became necessary to assess the combined influence of phosphorus and zinc on sorghum development and its indices, and this experiment was intended to do so.

MATERIALS AND METHODS

The field experiment was conducted at Regional Research Station, Bawal (Rewari) of Chaudhary Charan Singh Haryana Agricultural University, Hisar during *Kharif*, 2018 with variety HJ 513 in split-plot design and was replicated thrice. Treatments comprised of four phosphorus levels in the main plot *i.e.* T_1- Control, T_2- 7.5 kg P_2O_5/ha, T_3- 15 kg P_2O_5/ha, and T_4- 22.5 kg P_2O_5/ha and four zinc levels in subplot treatments *viz.* S_1- Control, S_2- 0.50 % foliar application of $ZnSO_4$ at 20-25 DAS, S_3- 0.75 % foliar spray of $ZnSO_4$ at 20-25 DAS and S_4- 25 kg $ZnSO_4$ ha^{-1} as basal dose. A composite sample was prepared from the experimental field and estimated for the Physico-chemical properties of the soil. The OC(%), pH (1:2), EC (dS/m), available N (kg/ha), P (kg/ha), K (kg/ha) and Zn (ppm) of the experimental soil were 0.23, 8.20, 0.12, 143.3, 13.4, 187.6 and 0.55, respectively.

Five plants from each plot were selected randomly and were tagged. For the calculation of the number of leaves, leaves from each tagged plant were calculated and the average of five was taken as the number of leaves/plant. Fresh leaves were harvested from three random plants and leaf area was measured with leaf area meter and the average of three was worked out. The leaf area index (LAI) is the ratio between leaf area to ground area.

$$LAI = \frac{\text{Leaf area (cm}^2)}{\text{Ground area (cm}^2)}$$

CGR represents the dry weight gained by plant material per unit of time. It was computed as:

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{\text{Land area (m}^2)}$$

Where W_1 and W_2 dry matter accumulation at time t_1 and t_2 respectively.

Relative growth rate (mg/g/day) represents the increase of plant material per unit weight per unit time and is expressed mathematically as given by Fisher (1921).

$$RGR = \frac{\text{Log } W_2 - \text{Log } W_1}{t_2 - t_1}$$

Where W_1 and W_2 dry matter accumulation at time t_1 and t_2 respectively.

Net assimilation rate (mg/cm²/day) the rate of net photosynthesis was indirectly indicated by NAR. It is represented as g of dry matter production per cm^2 leaf area.

$$NAR = \frac{(W_2 - W_1)(\text{Log } L_2 - \text{Log } L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

Where,

L_1 and W_1 = Leaf area and dry weight of the plant, respectively at time t_1.

L-$_2$ and W_2 = Leaf area and dry weight of the plant, respectively at time t_2.

RESULTS AND DISCUSSION

Growth parameters

Data presented in Table 2 and 3 revealed that the number of leaves per plant and leaf area index was significantly affected by different levels of phosphorous and zinc. Application of phosphorus @ 25 kg P_2O_5/ha resulted in a significantly higher number of leaves per plant (8.21 and 12.08, at 40 DAS and

TABLE 2
Effect of phosphorus and zinc levels on periodical changes in the number of leaves/plant of fodder sorghum

Treatments	Number of leaves/ plant			
	20 DAS	40 DAS	60 DAS	At harvest
Phosphorous levels				
P_1- Control	5.16	6.66	8.63	9.84
P_2- 7.5 kg/ha	5.74	7.29	9.54	10.78
P_3- 15 kg/ha	6.23	7.86	10.12	11.64
P_4- 22.5 kg/ha	6.62	8.21	10.59	12.08
SEm ±	0.09	0.12	0.13	0.06
CD at 5%	0.28	0.34	0.38	0.22
Zinc levels				
Z_1- Control	5.53	6.91	8.87	10.17
Z_2- 0.50 % foliar $ZnSO_4$	5.72	7.49	9.68	10.91
Z_3- 0.75 % foliar $ZnSO_4$	5.79	7.61	9.85	11.19
Z_4- 25 kg basal $ZnSO_4$	6.39	8.01	10.28	11.88
SEm ±	0.06	0.07	0.10	0.12
CD at 5%	0.19	0.23	0.29	0.34

TABLE 3
Periodical changes in LAI of fodder sorghum as influenced by phosphorus and zinc levels

Treatments	Leaf area index			
	20 DAS	40 DAS	60 DAS	At cutting
Phosphorous levels				
P_1- Control	1.25	2.22	3.18	3.53
P_2- 7.5 kg/ha	1.41	2.51	3.41	3.84
P_3- 15 kg/ha	1.54	2.76	3.61	4.19
P_4- 22.5 kg/ha	1.63	2.91	3.79	4.36
SEm ±	0.03	0.04	0.05	0.04
CD at 5%	0.07	0.13	0.16	0.11
Zinc levels				
Z_1- Control	1.39	2.41	3.29	3.69
Z_2- 0.50 % foliar $ZnSO_4$	1.44	2.57	3.46	3.98
Z_3- 0.75 % foliar $ZnSO_4$	1.45	2.62	3.51	4.04
Z_4- 25 kg basal $ZnSO_4$	1.56	2.79	3.68	4.26
SEm ±	0.02	0.03	0.04	0.03
CD at 5%	0.05	0.10	0.13	0.09

cutting, respectively) and leaf area index (2.91 and 4.36, at 40 DAS and cutting, respectively) as compared to rest of the treatments.

Among different levels of Zn application, application of $ZnSO_4$ @ 25 kg/ha as basal dose resulted in the significantly greater number of leaves per plant (8.01 and 11.88, at 40 DAS and cutting, respectively), and leaf area index (2.79 and 4.26, at 40 DAS and cutting, respectively) of fodder sorghum at all growth stages (and at cutting respectively) over other treatments whereas foliar application of Zn @ 0.50 % and 0.75 %, respectively, found at par with each other at all the stages except 20 DAS.

With an increase in the level of phosphorus and zinc, vegetative growth of the plant is enhanced resulting in better growth. These results are in line with Ayub *et al.* (2002), Grazia *et al.* (2003) Piri (2012), Roy *et al.* (2015).

Physiological parameters

Crop growth rate (CGR), Relative growth rate (RGR), and net assimilation rate (NAR)

Different levels of phosphorus and zinc showed a significant increase in Crop Growth Rate (CGR), Relative Growth Rate (RGR), and Net Assimilate Rate (NAR) in comparison to control as presented in Table 4, 5, and 6. Application of phosphorus @ 22.5 kg P_2O_5/ha resulted in significantly better CGR (9.83 and 3.06, at 20-40 DAS and cutting, respectively), RGR (80.81 and 60.28, at 20-40 DAS and cutting, respectively), and NAR (18.63 and 11.37, at 20-40 DAS and cutting, respectively) than rest of the treatments.

Basal application of $ZnSO_4$ @ 25 kg/ha recorded significantly higher CGR (9.83 and 3.06, at 20-40 DAS and cutting, respectively), RGR (80.81 and 60.28, at 20-40 DAS and cutting, respectively), and NAR (18.63 and 11.37, at 20-40 DAS and cutting, respectively) of fodder sorghum over control and foliar

TABLE 4
Effect of phosphorus and zinc levels on periodical changes in crop growth rate of fodder sorghum

Treatments	Crop growth rate (g/m²/day)			
	0-20 DAS	20-40 DAS	40-60 DAS	60-cutting
Phosphorous levels				
P_1- Control	1.87	8.71	5.31	2.83
P_2- 7.5 kg/ha	2.08	9.18	5.59	2.92
P_3- 15 kg/ha	2.22	9.57	5.78	2.99
P_4- 22.5 kg/ha	2.37	9.83	5.95	3.06
SEm ±	0.04	0.08	0.06	0.02
CD at 5%	0.13	0.23	0.19	0.05
Zinc levels				
Z_1- Control	2.02	8.89	5.48	2.87
Z_2- 0.50 % foliar $ZnSO_4$	2.11	9.32	5.68	2.94
Z_3- 0.75 % foliar $ZnSO_4$	2.14	9.47	5.72	2.83
Z_4- 25 kg basal $ZnSO_4$	2.31	9.69	5.85	2.94
SEm ±	0.03	0.06	0.03	0.01
CD at 5%	0.08	0.17	0.10	0.03

TABLE 5
Effect of phosphorus and zinc levels on periodical changes in relative growth rate of fodder sorghum

Treatments	Relative growth rate (mg/g/day)			
	0-20 DAS	20-40 DAS	40-60 DAS	60-At harvest
Phosphorous levels				
P_1- Control	44.78	78.08	67.23	59.08
P_2- 7.5 kg/ha	47.1	79.48	68.32	59.76
P_3- 15 kg/ha	49.09	80.29	69.37	60.11
P_4- 22.5 kg/ha	49.92	80.81	69.98	60.28
SEm ±	0.08	0.11	0.10	0.04
CD at 5%	0.23	0.35	0.29	0.13
Zinc levels				
Z_1- Control	46.42	78.98	68.17	59.42
Z_2- 0.50 % foliar $ZnSO_4$	47.37	79.65	69.02	59.81
Z_3- 0.75 % foliar $ZnSO_4$	47.63	79.79	69.18	59.86
Z_4- 25 kg basal $ZnSO_4$	49.27	80.47	69.63	60.09
SEm ±	0.12	0.07	0.08	0.03
CD at 5%	0.35	0.22	0.23	0.10

TABLE 6
Effect of phosphorus and zinc levels on periodical changes in net assimilation rate of fodder sorghum

Treatments	Net assimilation rate (mg/cm^2 leaf area/day)			
	0-20 DAS	20-40 DAS	40-60 DAS	60-At harvest
Phosphorous levels				
P_1- Control	2.70	17.32	12.87	10.75
P_2- 7.5 kg/ha	2.84	17.84	13.41	11.02
P_3- 15 kg/ha	2.95	18.28	13.86	11.23
P_4- 22.5 kg/ha	3.07	18.63	14.16	11.37
SEm ±	0.03	0.06	0.08	0.03
CD at 5%	0.08	0.19	0.22	0.11
Zinc levels				
Z_1- Control	2.77	17.57	12.99	10.82
Z_2- 0.50 % foliar $ZnSO_4$	2.83	18.08	13.74	10.93
Z_3- 0.75 % foliar $ZnSO_4$	2.86	18.14	13.71	10.97
Z_4- 25 kg basal $ZnSO_4$	3.01	18.41	14.98	11.19
SEm ±	0.02	0.04	0.06	0.02
CD at 5%	0.06	0.13	0.17	0.07

spray. However, treatment with the foliar application was at par with each other at all the crop growth stages except at 20 DAS. Significant changes in physiological indices such as CGR, RGR, and NAR were found when Zn levels increased. The amount of solar energy intercepted by plants increases as the leaf area index increases, which could be attributed to improved root development by Phosphorus and higher Zn uptake, which leads to higher photosynthetic efficiency. Similar results were reported by Zhoori *et al.* (2009) and Chaab *et al.* (2011), Dwiwedi *et al.* (1987) and Ayub *et al.* (2002).

CONCLUSION

Based on the one year experimental results, it can be concluded that application of phosphorus and zinc improved the growth and physiological parameters of fodder sorghum. Basal applications of 22.5 kg P_2O_5/ha and 25 kg $ZnSO_4$/ha aid in improved crop growth, relative growth rate, and net assimilation rate.

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