Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2017; 6(4): 110-114
Received: 06-05-2017
Accepted: 05-06-2017

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Effect of soil moisture conservation practices and seed hardening on growth, yield, nutrient content, uptake and quality of pearl millet [*Pennisetum glaucum* (L.) R. Br.]

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Abstract
A field experiment was conducted during *kharif* 2013 on loamy sand soil at Agronomy Farm, College of Agriculture, SKRAU, Bikaner to study the effect of moisture conservation practices on pearl millet. Result revealed that modification in surface configuration as ridge and furrow, plastic mulch and pre sowing seed hardening with KNO_3 significantly increased dry matter accumulation and total number of tillers/plant, ear head length, test weight, grain yield, stover yield and biological yield also significantly increased with the modification in surface configuration as ridge and furrow method over flat sowing, straw and dust mulch and without seed hardening. Modification in surface configuration as ridge and furrow, plastic mulch and pre sowing seed hardening with KNO_3 enhanced grain yield to the tune of 22.21, 14.40 and 48.82 and 10.50 per cent over flat sowing, straw and dust mulch and without seed hardening.

Keywords: mulch, moisture, yield, seed hardening, pearl millet

1. Introduction
Pearl millet [*Pennisetum glaucum* (L.) R. Br.] commonly known as bajra, is an important drought hardy millet crop basically cultivated in the arid and semi-arid areas on light textured sandy soils. It is one of the major coarse grain crop and is considered to be a poor man's food as it provides staple food for the poor in a short period. It is a dual purpose crop, grains are used for human consumption and its fodder as cattle feed. Pearl millet grains are eaten cooked like rice or 'chapattis' are prepared out of flour like wheat or maize flour. It is also used as feed for poultry and green fodder or dry *karbi* for cattle. India is the largest producer of pearl millet with an annual production of 10.05 million tonnes from an area of 8.69 million ha and productivity of 1156 kg ha^{-1} (AICMIP, 2014). Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana are the major pearl millet growing states. Together they contribute approximately 95 per cent of total area and production of the country. Rajasthan constitutes about 50% area and 42% of production of pearl millet in the country. Rajasthan ranks first in area (46 lakh ha) and production (28 lakh tonnes). Average productivity of pearl millet in Rajasthan is 400 kg ha^{-1} (www.rajasthankrishi.gov.in, 2013). Availability of soil moisture till maturity of crop is very important to realize its yield potential. Soil moisture conservation practices such as modification in surface configuration by making ridge and furrow after sowing and use of mulches may help to conserve soil moisture and enhances availability of soil moisture for a longer duration for better crop production. Meena, *et al*., (2013) [6] observed beneficial results under ridge and furrow over flat sowing. Mulching is also one of the most important cultural technologies for conserving moisture in rain fed farming system. Mulch is reported to conserve soil moisture, protect soil from erosion, reduce soil temperature, minimize evaporation loss and enhance root growth. Favorable effects of mulching on yield of different crops were reported by many scientists '*viz.* Gupta and Bhan (1993) [3] in maize, Bhan, *et al.*, (1995) [2] in sorghum. Drought induced losses in crop yield probably exceed losses from all other causes, since both the severity and duration of the stress are critical. Various management strategies have been proposed to cope up with drought stress. Pre-sowing seed hardening with different chemicals improve seed viability as well as vigour, root length, root-shoot ratio and yield. Chemicals like KNO_3 at variable concentrations promote germination of seeds, improve seedling growth, activity of various hydrolyses, solubilisation and mobilization of nitrogen from cotyledons to growing embryo, rate of water uptake, resulting in improvement of nitrate content and enhanced yield in various crops(Kaur, *et al*., 2003; Sharma

and Bose, 2006) [5, 9]. Salicylic acid is a phenolic plant growth regulator having a role in regeneration of physiological processes in plants (Sakhabutinova, *et al*., 2003) [8]. Use of chemicals that have action at targeted sites in plant metabolism can improve physiological activities. Thus, seed hardening is a practice adopted to make crop plants resistant to soil moisture stress.

Material and Methods

The experiment was conducted at the Agronomy farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner during the *kharif* 2013. Geographical location of Bikaner is between 72.55^0 to 73.42º E longitude and 28.00^0 to 28.16º N latitude at an altitude of 234.70 meters above mean sea level. The area has arid ecosystem (hot arid eco-region with desert and saline soil), which is characterized by deep, sandy and coarse loamy, desert soils with low water holding capacity, hot and arid climate. The total rainfall received during the crop growth period was 151.5 mm during 2013-14 in 13 rainy days during the growing season. Weekly mean evaporation ranged from 6.1 to 10.4 mm per day during the crop growing period. The maximum and minimum temperature during the crop growth period ranged between 33.3 ^{0}C to 37.0 ^{0}C and 13.1 ^{0}C to 25.1 ^{0}C during 2013-14. The soil was medium clayey in texture and slightly alkaline in reaction with pH (8.22) and EC (0.16 dS m^{-1}), low in available N (87.85 kg ha^{-1}), and medium in available P (19.02 kg ha^{-1}) and available K (234.70 kg ha^{-1}). The eighteen treatment combinations comprising of modification in surface configuration as ridge and furrow at 20 DAS and flat sowing and dust, straw and plastic mulch as main plot treatments. Sub plot treatment comprised of seed hardening with KNO_3 0.02%, salicylic acid 100 ppm and without seed hardening. The treatments were laid out in split plot design with four replications. The test pearl millet variety "RHB-177" was sown by *kera* method at 45 x10 cm spacing using seed rate of 4 kg ha^{-1}. The recommended dose of fertilizers i.e. 40 kg N ha^{-1}, 20 kg P_2O_5 ha^{-1} and 30 kg K_2O ha^{-1} applied at the sowing as basal which was applied through urea, single superphosphate and murate of potash, respectively. Waste straw mulch of pearl millet @ 2.5 t ha^{-1} was spread over the soil surface between the rows of crop.

Results and discussion

Effect on growth parameters

The modification of surface configuration technology did not significant influenced on plant stand at 20 DAS and harvest and plant height at 30, 60 DAS and harvest. Dry matter accumulation at 30, 60 DAS and harvest, number of tillers/plant were highly influenced by the modification in surface configuration as ridge and furrow, plastic mulch and pre sowing seed hardening with KNO3 and salicylic acid compared to flat method of sowing, dust, straw mulch and without seed hardening. The method of modification in surface configuration after 20 DAS aided in conservation rain water and its availability for longer duration, mini barriers in run-off of water and increased moisture in turn might have helped in the rapid cell division and multiplication and resulted in expansion of leaf area with increased chlorophyll content. As a result the photosynthetic rate might have increased, which ultimately increased the supply of carbohydrates to the plants which in turn increased the vertical and lateral growth of the plants leading to the better plant height, dry matter accumulation. Application of plastic mulch in between rows, through small holes made on the film, besides conserving more rain water in soil profile along with comparatively more reduction in evaporation losses might have resulted in availability of more soil moisture for longer duration compared to straw and dust mulch. Significantly increase in growth parameters due to pre sowing seed hardening with KNO_3 might be because of early seed germination improved seed vigour, increase in root length, root-shoot ratio, improved seedling growth, increase in activity of various hydrolyses, delayed the onset of moisture stress within the plant due to more retention of water, more moisture conservation and avoidance of desiccation, resulting into increased growth parameters. Singh and Verma (1996) [10] also reported similar result.

Effect on yield and yields attributes

The different soil moisture and seed hardening treatments significantly influenced yield attributing and yields of pearl millet. A significant increase in yield and yield attributes viz., except harvest index, ear head length, ear head diameter, test weight, grain yield, stover yield, biological yield were observed under modification in surface configuration as ridge and furrow, plastic mulch and pre sowing seed hardening with KNO_3 and salicylic acid compared to flat method of sowing, dust, straw mulch and without seed hardening. Yield attributes and yield could be attributed to improvement in growth attributes through availability of more moisture and nutrients, which in turn favourably influenced number of physiological processes like transpiration, photosynthesis and build-up of food material. Increase in yield attributes in pearl millet ultimately led to increased grain yield in ridge and furrow, plastic mulch and pre sowing seed hardening with KNO_3 and salicylic acid technology over flat sowing, dust mulch and without hardening (Singh and Verma 1996) [10]. The increase in grain yield with increase in yield attributes may also be supported by significant and positive correlation between grain yield and yield attributes. The linear relationship between grain yield and these parameters is an additional evidence for increase in grain yield with increase in yield attributing characters. These results are in conformity with findings of Tetarwal and Rana (2006) [12], Jalota, *et al*., (2007) [4] Menaka, *et al*., (2008) [7] and Sujatha, et al., (2013) [11].

Table 1: Effect of moisture conservation practices and seed hardening on plant stand of Pearl millet at different stages

Treatments	Plant stand per metre row length	
	20 DAS	At harvest
Modification in surface configuration		
Flat sowing (S_1)	7.19	7.05
Ridge and furrow (S_2)	7.44	7.27
S.Em ±	0.10	0.11
CD(P=0.05)	NS	NS
Mulching		
Dust mulch (M_1)	7.28	7.12
Straw mulch (M_2)	7.32	7.17
Plastic mulch (M_3)	7.35	7.19
S.Em ±	0.12	0.13
CD(P=0.05)	NS	NS
Seed hardening		
No seed hardening(H_1)	7.23	7.08
KNO_3 0.02%(H_2)	7.43	7.26
Salicylic acid 100 ppm(H_3)	7.29	7.13
S.Em ±	0.13	0.10
CD(P=0.05)	NS	NS

Table 2: Effect of moisture conservation practices and seed hardening on plant height of Pearl millet at different growth stages

Plant height (cm)			
Treatments	**30 DAS**	**60 DAS**	**At harvest**
Modification in surface configuration			
Flat sowing (S_1)	25.95	130.46	142.22
Ridge and furrow (S_2)	28.04	132.39	144.33
S.Em ±	0.71	1.23	1.34
CD(P=0.05)	NS	NS	NS
Mulching			
Dust mulch (M_1)	26.39	115.24	125.63
Straw mulch (M_2)	26.80	130.14	141.88
Plastic mulch (M_3)	27.81	148.89	162.31
S.Em ±	0.87	1.51	1.64
CD(P=0.05)	NS	4.54	4.95
Seed hardening			
No seed hardening (H_1)	26.53	127.62	139.13
KNO_3 0.02%(H_2)	27.38	135.36	147.56
Salicylic acid 100 ppm(H_3)	27.08	131.30	143.14
S.Em ±	0.83	0.24	0.26
CD(P=0.05)	NS	0.68	0.74

Table 3: Effect of moisture conservation practices and seed hardening on dry matter accumulation of Pearl millet at different growth stages

Dry matter (g) per metre row length			
Treatments	**30 DAS**	**60 DAS**	**At harvest**
Modification in surface configuration			
Flat sowing (S_1)	17.06	104.66	143.52
Ridge and furrow (S_2)	20.88	127.98	165.28
S.Em ±	0.19	1.09	1.45
CD(P=0.05)	0.56	3.28	4.36
Mulching			
Dust mulch (M_1)	15.03	102.00	135.39
Straw mulch (M_2)	19.51	115.18	152.89
Plastic mulch (M_3)	22.37	131.77	174.91
S.Em ±	0.23	1.33	1.77
CD(P=0.05)	0.69	4.02	5.34
Seed hardening			
No seed hardening (H_1)	17.99	112.95	149.93
KNO_3 0.02% (H_2)	19.84	116.21	159.02
Salicylic acid 100 ppm (H_3)	19.08	115.96	154.25
S.Em ±	0.25	0.21	0.28
CD (P=0.05)	0.72	0.60	0.80

Table 4: Effect of moisture conservation practices and seed hardening on total number of tillers, Ear head length and ear head diameter of Pearl millet

Treatments	**No. of tillers/plant**	**Ear head length (cm)**	**Ear head diameter(cm)**
Modification in surface configuration			
Flat sowing (S_1)	3.94	16.55	1.44
Ridge and furrow (S_2)	4.54	20.61	1.81
S.Em ±	0.04	0.17	0.02
CD(P=0.05)	0.11	0.52	0.05
Mulching			
Dust mulch (M_1)	3.72	16.34	1.42
Straw mulch (M_2)	4.20	18.56	1.61
Plastic mulch (M_3)	4.81	20.84	1.83
S.Em ±	0.05	0.21	0.02
CD(P=0.05)	0.14	0.63	0.06
Seed hardening			
No seed hardening(H_1)	4.12	18.60	1.615
KNO_3 0.02%(H_2)	4.37	18.60	1.631
Salicylic acid 100 ppm(H_3)	4.24	18.53	1.617
S.Em ±	0.01	0.02	0.00006
CD(P=0.05)	0.02	0.06	0.00017

Table 5: Effect of moisture conservation practices and seed hardening on effective tillers, No. of Grains and Test weight of Pearl millet

Treatments	**Effective tillers/plant**	**No. of grains/ ear**	**Test weight (g)**
Modification in surface configuration			
Flat sowing (S_1)	2.26	725.53	6.02
Ridge and furrow (S_2)	2.59	894.82	7.56
S.Em ±	0.02	7.58	0.07
CD(P=0.05)	0.06	22.86	0.21
Mulching			
Dust mulch (M_1)	2.13	711.51	5.94
Straw mulch (M_2)	2.40	802.35	6.75
Plastic mulch (M_3)	2.74	916.66	7.66
S.Em ±	0.03	9.29	0.09
CD(P=0.05)	0.08	28.00	0.26
Seed hardening			
No seed hardening(H_1)	2.35	807.19	6.74
KNO_3 0.02%(H_2)	2.50	815.14	6.86
Salicylic acid 100 ppm(H_3)	2.42	808.20	6.76
S.Em ±	0.04	0.03	0.05
CD(P=0.05)	0.13	0.09	NS

Table 6: Effect of moisture conservation practices and seed hardening on grain yield and stover yield of Pearl millet

Treatments	**Grain yield (Kg ha^{-1})**	**Stover yield (Kg ha^{-1})**
Modification in surface configuration		
Flat sowing (S_1)	1708	2962
Ridge and furrow (S_2)	2088	3618
S.Em ±	17.90	30.55
CD(P=0.05)	53.95	92.09
Mulching		
Dust mulch (M_1)	1503	2604
Straw mulch (M_2)	1955	3391
Plastic mulch (M_3)	2236	3875
S.Em ±	21.92	37.42
CD(P=0.05)	66.07	112.78
Seed hardening		
No seed hardening (H_1)	1798	3176
KNO_3 0.02% (H_2)	1987	3379
Salicylic acid 100 ppm (H_3)	1908	3315
S.Em ±	0.58	2.05
CD(P=0.05)	1.66	5.89

Table 7: Effect of moisture conservation practices and seed hardening on nitrogen content in grain and stover and their uptake by Pearl millet

Treatments	**Nitrogen content (%)**		**Nitrogen uptake (kg ha-1)**		
	Grain	**Stover**	**Grain**	**Stover**	**Total**
Modification in surface configuration					
Flat sowing (S_1)	1.436	0.474	24.96	14.72	39.68
Ridge and furrow (S_2)	1.807	0.596	38.38	21.30	59.68
S.Em ±	0.016	0.005	0.64	0.34	0.98
CD(P=0.05)	0.050	0.015	1.94	1.04	2.95
Mulching					
Dust mulch (M_1)	1.424	0.463	21.67	12.14	33.81
Straw mulch (M_2)	1.606	0.546	31.79	18.63	50.42
Plastic mulch (M_3)	1.835	0.596	41.55	23.56	65.11
S.Em ±	0.020	0.006	0.79	0.42	1.20
CD(P=0.05)	0.061	0.018	2.38	1.27	3.61
Seed hardening					
No seed hardening (H_1)	1.616	0.533	29.88	17.31	47.19
KNO_3 0.02% (H_2)	1.632	0.538	33.36	18.61	51.97
Salicylic acid 100 ppm (H_3)	1.618	0.534	31.44	18.10	49.54
S.Em ±	0.004	0.00002	0.10	0.01	0.10
CD(P=0.05)	0.010	0.00006	0.29	0.04	0.29

Table 8: Effect of moisture conservation practices and seed hardening on phosphorus content in grain and stover and their uptake by Pearl millet

Treatments	P content (%)		P uptake (kg ha-1)		
	Grain	Stover	Grain	Stover	Total
Modification in surface configuration					
Flat sowing (S_1)	0.230	0.109	3.99	3.40	7.39
Ridge and furrow (S_2)	0.289	0.138	6.14	4.92	11.06
S.Em ±	0.003	0.001	0.10	0.08	0.18
CD(P=0.05)	0.008	0.003	0.30	0.24	0.53
Mulching					
Dust mulch (M_1)	0.228	0.107	3.43	2.80	6.23
Straw mulch (M_2)	0.257	0.126	5.09	4.30	9.39
Plastic mulch (M_3)	0.294	0.138	6.65	5.37	12.02
S.Em ±	0.003	0.001	0.12	0.10	0.22
CD(P=0.05)	0.010	0.004	0.37	0.29	0.65
Seed hardening					
No seed hardening (H_1)	0.259	0.123	4.78	4.00	8.78
KNO_3 0.02% (H_2)	0.261	0.124	5.34	4.30	9.64
Salicylic acid 100 ppm (H_3)	0.259	0.123	5.08	4.18	9.26
S.Em ±	0.001	0.00005	0.03	0.003	0.03
CD(P=0.05)	NS	0.00013	0.10	0.008	0.09

Table 9: Effect of moisture conservation practices and seed hardening on potassium content in grain and stover and their uptake by Pearl millet

Treatments	K content (%)		K uptake (kg ha-1)		
	Grain	Stover	Grain	Stover	Total
Modification in surface configuration					
Flat sowing (S_1)	0.574	2.187	9.98	67.92	77.90
Ridge and furrow (S_2)	0.721	2.752	15.35	98.32	134.67
S.Em ±	0.006	0.023	0.24	1.59	1.83
CD(P=0.05)	0.018	0.070	0.73	4.78	5.50
Mulching					
Dust mulch (M_1)	0.568	2.136	8.67	56.01	64.68
Straw mulch (M_2)	0.642	2.519	12.72	85.98	98.70
Plastic mulch (M_3)	0.734	2.752	16.62	107.37	123.99
S.Em ±	0.007	0.028	0.30	1.94	2.24
CD(P=0.05)	0.022	0.085	0.90	5.86	6.74
Seed hardening					
No seed hardening (H_1)	0.645	2.460	1.95	79.91	91.86
KNO_3 0.02% (H_2)	0.653	2.484	13.35	85.91	99.26
Salicylic acid 100 ppm (H_3)	0.646	2.463	12.70	83.55	96.25
S.Em ±	0.001	0.0001	0.03	0.06	0.07
CD(P=0.05)	0.003	0.0003	0.08	0.17	0.19

Effect on nutrient content and uptake

Nutrient content and uptake by the grain and stover of pearl millet increased significantly due to modification in surface configuration. The increased in NPK content in seed and stover as well as their uptake by the plant might be outcome of the availability of these respective nutrients to the seed and stover. Increased content and uptake was also observed by Singh and Verma (1996) [10] who reported increased N uptake under ridge and furrow sowing. The increased availability of soil moisture under straw and plastic mulch and reduced evaporation losses under straw and plastic mulch might have resulted in increased soil moisture as well as for longer duration might have resulted in availability of more N, P, K in soil moisture and there by greater uptake by plant, comparatively more reduction in evaporation losses under plastic mulch. Yadav (2005) [14] reported significantly higher concentration of N, P and K in seed and stover with the application of black polythene, *Tephrosia* and *Saccharum.* Tetarwal and Rana (2006) [12] reported that application of straw mulch recorded significantly higher nutrient uptake. Seed hardening exhibited significant increase in nitrogen, phosphorus and potassium content in seed and uptake of N, P, and K by grain and stover and total uptake. Plant growth substances such as salicylic acid, auxins, gibberellins, cytokinin and abscisic acid modulate the plant responses towards drought. Thus, more availability of soil moisture under treated plots might have resulted in transport of these nutrients with in plants, there by more content and uptake was recorded. Also these chemicals act as antioxidants and reduce the adverse effects of water deficit.

Conclusion

Thus, it is concluded that modification in surface configuration as ridge and furrow, application of plastic mulch and seed hardening with KNO_3 proved effective in enhancing grain yield under uncertain environment of the arid region and found to be the most effective treatments for meeting the production potential and profitability of pearl millet under rain fed condition.

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