

Yield, quality and nutrient status of pearl millet (*Cenchrus americanus*) as replacement crop after stand failure in sandy soil under different tillage, herbicide and planting delay

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ABSTRACT

A field experiment was carried out during the rainy (*khari*) seasons of 2018 and 2019 at Bikaner, Rajasthan, to study the effect of tillage, herbicide and planting delay on nutrient, yield and quality of pearl millet [*Cenchrus americanus* (L.) Morrone; syn. *Pennisetum glaucum* (L.) R. Br.] as replacement crops following pearl millet stand failure in arid Rajasthan. The experiment was laid out in strip-plot design in 3 factors with 24 treatments comprising 4 tillage (T₁: no-tillage; T₂: tillage with disc plough with planking; T₃: tillage with cultivator with planking; T₄: tillage with harrow with planking), 2 herbicide (H₀: control; H₁: atrazine 0.5 kg a.i/ha) and 3 planting delay (P₁: 10 days after herbicide application; P₂: 20 days after herbicide application; P₃: 30 days after herbicide application) treatments, times replicated 3 time. The disc plough (T₂) and early planting (10 July) P₁ significantly increased N, P, K, total nutrient uptake, partial nutrient balance (PBN), and nutrient efficiency ratio (NER) than the other treatments. The grain, stover, and crude protein yields of pearl millet were found significantly higher with disc plough and early planting (10 July) treatment compared to other treatments on pooled basis. The interactions were found non-significant between tillage × herbicide × planting delay in yield of pearl millet.

Key words: Pearl millet, Tillage, Herbicide, Planting delay, Nutrient, NER and PNB

Pearl millet is one of the most extensively cultivated cereals in the world, ranking sixth after rice, wheat, maize, barley and sorghum in terms of area. It is considered to be a poor man's food and popularly known as candle millet, cattail millet, bulrush millet or *bajra* (FAO, 2008). It is a principal cereal cultivated in drought-prone semi-arid regions of Africa and Indian subcontinent, mostly for food purpose. India has the largest area under pearl millet in the world, occupying 7.45 million hectares with the production of 9.72 million tonnes with an average productivity of 1,305 kg/ha (Anonymous, 2019). In India, the major producer states of pearl millet are Rajasthan, Uttar Pradesh, Maharashtra, Gujarat and Haryana. Rajasthan stands as number one state, with a share of about 57.57% area in the country and accounted for 49.64% of the pearl millet production (Anonymous, 2019). In Rajasthan, pearl millet is

an important crop, occupying 4.15 million ha producing 4.15 million tonnes with a productivity of 1,001 kg/ha (Anonymous, 2019). Crop residues are major source for livestock feed and constitute about 40–60% of total dry matter intake in livestock. At present, India faces a net deficit of 10.9% dry-crop residues. The demand of dry fodder will reach to 631 million tonnes by the year 2050 and at the current level of growth in forage resources, there will be 13.2% deficit in dry fodder in the year 2050 (Choudhary *et al.*, 2019).

Atrazine residues may affect the production of these rainy (*khari*) crops as a replacement crop, after stand failure of pearl millet. The residual effect of atrazine could be minimized by using better inputs, proper production technology, delaying planting of replacement crops and adoption of appropriate tillage methods. Out of these, tillage and delaying planting of replacement crops can be effective tools in reducing residual effect of herbicides by dilution as well as degradation (Soltani *et al.*, 2011). Several tillage implements performe different types of tillage such as disc plough, harrow and cultivators, but performance in reducing the residual effect of herbicides is different depending on soil types. So there is a need to test various tillage meth-

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ods to reduce the immediate residual effect of atrazine on replacement crops, particularly in sandy soils of Rajasthan.

The tillage, herbicide and planting delay enhanced yield and could results in increased N, P and K content and partial nutrient balance (PBN) in the grain and stover. Therefore, the objective of this article was to assess the effect of tillage, herbicide and planting delay on nutrient, yield and quality of pearl millet as replacement crops following pearl millet stand failure in arid Rajasthan.

MATERIALS AND METHODS

The experiment was conducted at the Agronomy Farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University (SKRAU), Bikaner, during the rainy (*kharif*) seasons of 2018 and 2019. The farm is situated on Bikaner-Sriganganagar road at 28°4'21" N and 73°20'17" E, 234.7 m above the mean sea-level. According to the National Planning Commission, it falls under Agro-climatic zone XIV (Western Dry Region) of India. The soil was sandy loam with pH 8.47 and 8.40, available N 122 and 119.5 kg/ha (Subbiah and Asija, 1956), available P 36 and 34 kg/ha (Olsen *et al.*, 1954), available K 325 and 320 kg/ha (Metson, 1956) and 0.12 and 0.14% organic carbon (Walkley and Black, 1947). Recommended dose of fertilizers 60, 40 kg/ha (N₂ and P₂O₅, respectively) were applied basal at the time of sowing. The remaining half dose of N was top-dressed through urea at 25 days after sowing (DAS). Pearlmillet recommended dose for irrigated condition were applied. The nitrogen through

kjeldahl's method (Snell and Snell, 1949), phosphorus through vanadomolybdo phosphoric acid, yellow colour method (Jackson, 1973), and potassium through tri-acid digested material by using flame photometer (Richards, 1954) content in plants samples were determined in grain and stover of pearlmillet. The nutrient uptake of pearlmillet crop at harvesting was computed as: Total uptake (kg/ha) = (nutrient conc. in grain (%) × grain yield (kg/ha) + nutrient conc. in stover (%) × stover yield (kg/ha))/100. Nutrient efficiency ratio (kg/kg) (NER) = (Biological yield/Nutrient uptake). Partial nutrient balance (kg/kg) (PBN) = (Nutrient uptake by biological yield/Total nutrient applied) calculated as per Lal and Saini (2016). The experiment was laid out in strip-plot design in 3 factors with 24 treatments, comprising 4 tillage, 2 herbicide and 3 planting delay treatments. Statistical analysis was done by using STAR (R-Packages 1.5 STAR 2.0.) (Statistical Tool for Agricultural Research), software developed by Department of Plant Breeding Genetics and Biotechnology, IRRI (International Rice Research Institute), Manila, Philippines.

RESULTS AND DISCUSSION

Grain and stover yield

The tillage operations (Table 1) in pearl millet clearly exhibited that the grain and stover yields (1,892 kg/ha and 4,611 kg/ha, respectively) in T₂ (disc plough) was significantly superior over T₄ (disc harrow), T₃ (cultivator) and T₁ (no-tillage) treatments, while T₄ and T₃ tillage operations were found to be statistically at par with each other, but T₄

Table 1. Effect of tillage, herbicide and planting delay on nitrogen, phosphorus, potassium content and yield of pearl millet as replacement crop (pooled data of 2years)

Treatments	Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)		Yield (kg/ha)	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
<i>Tillage</i>								
T ₁ , No-tillage	1.62	0.55	0.24	0.13	0.71	1.15	1,310	3,675
T ₂ , Tillage with disc plough with planking	1.63	0.60	0.26	0.15	0.75	1.21	1,892	4,611
T ₃ , Tillage with cultivator with planking	1.59	0.58	0.24	0.14	0.73	1.19	1,446	3,892
T ₄ , Tillage with harrow with planking	1.64	0.61	0.25	0.15	0.76	1.20	1,542	4,258
SEM±	0.04	0.02	0.01	0.01	0.30	0.04	37	111
CD (P=0.05)	NS	NS	NS	NS	NS	NS	114	343
<i>Herbicide</i>								
H ₀ , Control	1.63	0.59	0.25	0.14	0.74	1.19	1,549	4,127
H ₁ , Atrazine 0.5 kg/ha	1.62	0.58	0.25	0.15	0.73	1.19	1,546	4,091
SEM±	0.02	0.01	0.01	0.00	0.01	0.02	25	50
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
<i>Planting delay</i>								
P ₁ , 10 days after herbicide application	1.65	0.62	0.26	0.15	0.76	1.25	2,069	5,268
P ₂ , 20 days after herbicide application	1.62	0.57	0.25	0.15	0.73	1.18	1,524	4,067
P ₃ , 30 days after herbicide application	1.59	0.56	0.23	0.14	0.72	1.13	1,049	2,993
SEM±	0.03	0.02	0.01	0.00	0.02	0.03	38	88
CD (P=0.05)	NS	NS	NS	NS	NS	NS	124	286

treatment was significantly superior to T_1 tillage operations during the crop-growing season. On the basis of pooled data, the grain and stover yields were decreased by 18.5 and 7.6%, 23.6 and 15.6% and 30.8 and 20.3% in T_4 , T_3 and T_1 tillage operations, respectively, compared to disc plough treatment (T_2). The influence of different tillage treatments, as stated earlier, through increased availability of soil moisture and nutrients, which favourably influenced number of physiological processes like transpiration, photosynthesis and buildup of food material. Sankar *et al.* (2012) also recorded that, practicing deep tillage (conventional method also helps in loosening the seed bed for good soil aeration, better root growth and ultimately bumper crop growth. Gajri *et al.* (1994) also reported that deep tillage (DT) enhances rooting-system by lowering soil strength which helps in better uptake of water and nutrients from the deeper layers. Kahlon and Khurana (2017) reported that tillage effects on grain yield was recorded in deep tillage (DT) followed by no-tillage with residue (NT), strip tillage (ST) and conventional tillage (CT). Poorest yield so obtained under zero tillage practice further explains these contentions. Herbicide data clearly revealed that grain and stover yields of pearl millet were not affected significantly by atrazine residue. The grain and stover yields were significantly influenced by the delay planting and data revealed that the P_3 (30 July) and P_2 (20 July) planting delay significantly decreased the grain yield (1049 and 2993 kg/ha and 1524 and 4067 kg/ha, respectively) compared to the P_1 (2069 and 5268 kg/ha) which showed

the highest grain and stover yields. On the basis of pooled data on pearl millet plainly exhibited the significant reduction in the grain and stover yields under P_2 and P_3 planting to the tune of 26.34 and 22.79% and 49.29 and 43.18%, respectively, compared to the P_1 planting. Bacci *et al.* (1999) reported the high productive potential of the first sowing crops as comparison with the second sowing date. The results obtained in the present study are in conformity to those reported by Jan *et al.* (2015), Maurya *et al.* (2016) and ICAR - IACRP (2019).

Crude protein and crude protein yield: Various tillage operations, herbicide and planting delay were statistically at par in respect of crude protein in grain (Fig. 1). Higher nitrogen in seed is directly responsible for higher protein, as it is a primary component of amino acids which constitute the basis of protein (Choudhary *et al.*, 2016). The crude protein yield (194 kg/ha) in T_2 (disc plough) was significantly superior compared to T_4 (disc harrow), T_3 (cultivator) and T_1 (no-tillage) treatments, while T_4 and T_3 tillage operations were found to be statistically at par with each other (Fig. 1) However, T_4 treatment showed significantly higher crude protein yield than T_1 tillage operations. In case of herbicide, the crude protein yield of pearl millet was not affected significantly by atrazine residue. The P_3 (30 July) and P_2 (20 July) planting delay significantly decreased the grain yield (155 kg/ha and 105 kg/ha) compared to the P_1 (10 July) (213 kg/ha) which produced highest crude protein yield on the basis of pooled data. Choudhary *et al.* (2016) reported that higher availability of

Table 2. Effect of tillage, herbicide and planting delay on nitrogen, phosphorus and potassium uptake of pearl millet as a replacement crop (pooled data of 2 years)

Treatments	Nitrogen uptake(kg/ha)			Phosphorus uptake(kg/ha)			Potassium uptake(kg/ha)		
	Grain	Stover	Total	Grain	Stover	Total	Grain	Stover	Total
<i>Tillage</i>									
T_1 , No-tillage	21.3	20.1	41.4	3.16	4.88	8.04	9.42	42.6	52.0
T_2 , Tillage with disc plough with planking	30.9	28.2	59.1	4.99	7.15	12.14	14.4	56.6	71.1
T_3 , Tillage with cultivator with planking	22.9	22.7	45.6	3.50	5.51	9.01	10.4	46.7	57.2
T_4 , Tillage with harrow with planking	25.4	26.2	51.7	3.94	6.45	10.39	11.9	51.9	63.8
SEm±	0.90	0.86	1.05	0.13	0.29	0.30	0.43	2.12	2.26
CD (P=0.05)	2.77	2.65	3.24	0.39	0.89	0.91	1.32	6.55	6.96
<i>Herbicide</i>									
H_0 , Control	25.2	24.5	49.8	3.90	5.95	9.85	11.6	49.8	61.4
H_1 , Atrazine 0.5 kg/ha	25.1	24.0	49.2	3.89	6.04	9.93	11.5	49.1	60.6
SEm±	0.55	0.43	0.77	0.10	0.16	0.17	0.26	1.32	1.32
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
<i>Planting delay</i>									
P_1 , 10 days after herbicide application	34.0	32.7	66.8	5.48	7.86	13.33	15.8	66.2	82.1
P_2 , 20 days after herbicide application	24.7	23.3	48.1	3.78	5.96	9.73	11.2	48.3	59.5
P_3 , 30 days after herbicide application	16.7	16.7	33.5	2.44	4.17	6.62	7.63	33.9	41.5
SEm±	0.98	0.92	0.78	0.13	0.17	0.21	0.36	2.14	2.08
CD (P=0.05)	3.19	2.99	2.54	0.44	0.57	0.69	1.17	7.00	6.78

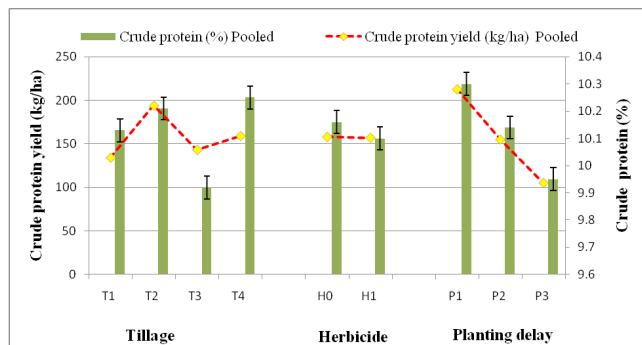


Fig. 1. Effect of tillage, herbicide and planting delay (T₁, no-tillage; T₂, tillage with disc plough with planking; T₃, tillage with cultivator with planking; T₄, tillage with harrow with planking; H₀, control; H₁, atrazine 0.5 kg a.i/ha; P₁, 10 days after herbicide application; P₂, 20 days after herbicide application; P₃, 30 days after herbicide application) on crude protein content and crude protein yield of pearl millet as replacement crop. Bar represents CD (P=0.05).

N resulted higher protein content. Higher grain yield and protein content led to higher protein yield. As protein yield is a function of protein content and grain yield.

Nutrient content: The tillage, herbicide and planting delay (Table 1) did not bring significant variation in the nitrogen, phosphorus, potassium content in grain and stover during both the years of analysis on pooled basis.

Nutrient uptake: The uptake of N, P and K by pearl millet was influenced significantly with tillage operations (Table 2). Uptake of nutrients by grain, stover and total

nutrient were significantly higher under T₂ (disc plough) over the T₄ (disc harrow), T₃ (cultivator) and T₁ (no-tillage) treatments. Similar trend was noted in respect of total nitrogen uptake also. Since the nitrogen uptake is primarily a function of dry matter accumulation (yield) and nitrogen content at cellular level, the reason of such significant variations could be assigned to the factors responsible for accumulation of dry matter in the plant and nitrogen content. Our results support the findings of Akter *et al.* (2003). No significant difference in the nutrient (N, P and K) uptake by grain, stover and total nutrients was observed in herbicide treatments. The different levels of planting delay significantly influenced the nutrient (N, P and K) uptake by grain, stover and total nutrient uptake. The significant increase in the total nutrient uptake was found with early planting P₁ (10 July) than the other planting delay treatments. Tomer (2017) also reported similar findings.

Partial nutrient balance: The partial nutrient balance of N and P was significantly influenced by tillage operations (Table 3). Nutrient balance of nitrogen by grain, stover and total nutrient balance were found significantly higher under T₂ (disc plough) over the T₄ (disc harrow), T₃ (cultivator) and T₁ (no-tillage) treatments. In case of herbicide, there was no significant difference in the nutrient (N and P) partial nutrient balance by grain, stover and total nutrient balance of pearl millet. Different planting delay significantly influenced the partial nutrient balance (N and P) by grain, stover and total nutrient balance. The significant increase in the total nutrient balance was found with early planting

Table 3. Effect of tillage, herbicide and planting delay on partial nutrient balance and nutrient efficiency ratio of pearl millet as a replacement crop (pooled data of 2 years)

Treatment	Nitrogen (Partial nutrient balance–Kg/Kg)			Phosphorus (Partial nutrient balance–Kg/Kg)			Nutrient efficiency ratio (Kg/Kg)		
	Grain	Stover	Total	Grain	Stover	Total	N	P	K
Tillage									
T ₁ , No-tillage	0.35	0.33	0.69	0.07	0.12	0.20	121.6	640.2	107.9
T ₂ , Tillage with disc plough with planking	0.51	0.47	0.98	0.12	0.17	0.30	111.5	549.1	93.2
T ₃ , Tillage with cultivator with planking	0.38	0.38	0.76	0.08	0.13	0.22	121.3	610.1	94.8
T ₄ , Tillage with harrow with planking	0.42	0.43	0.86	0.09	0.16	0.26	114.9	577.3	92.8
SEM±	0.02	0.01	0.02	0.00	0.01	0.01	4.10	17.40	5.74
CD (P=0.05)	0.04	0.04	0.05	0.01	0.02	0.02	NS	53.5	NS
Herbicide									
H ₀ , Control	0.42	0.40	0.83	0.09	0.14	0.24	118.0	597.3	97.6
H ₁ , Atrazine 0.5 kg/ha	0.41	0.40	0.82	0.09	0.15	0.24	116.6	591.0	96.8
SEM±	0.01	0.01	0.01	0.00	0.00	0.00	1.8	9.70	3.49
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting delay									
P ₁ , 10 days after herbicide application	0.56	0.54	1.11	0.14	0.19	0.33	111.2	570.0	98.0
P ₂ , 20 days after herbicide application	0.41	0.39	0.80	0.09	0.14	0.24	117.3	586.2	94.9
P ₃ , 30 days after herbicide application	0.27	0.27	0.55	0.06	0.10	0.16	123.3	626.4	98.5
SEM±	0.02	0.02	0.01	0.00	0.00	0.01	2.60	12.20	4.26
CD (P=0.05)	0.05	0.05	0.04	0.01	0.01	0.01	8.4	39.9	NS

P₁ (July 10) than with other planting delay treatments. These results confirm with the findings of Lal and Saini *et al.* (2016).

Nutrient efficiency ratio: Different tillage operations (Table 3) did not cause significant variation in the nitrogen and potassium nutrient efficiency ratio but, phosphorus was significantly affected by tillage, when disc plough (T₂) and disc harrow (T₄) were adopted which being at par with each other, but significantly lowest efficiency ratio compared to no-tillage (T₁) and cultivator (T₃) treatments. Herbicide did not cause significant variation in the nitrogen, phosphorus and potassium nutrient efficiency ratio. Planting delay P₁ (10 July) showed significantly lower efficiency ratio than P₃ (July 30) and P₂ (July 20) in nitrogen and phosphorus but potassium was non-significant at all planting. The results also noted similar with the findings of Lal and Saini *et al.* (2016).

CONCLUSION

Disc plough tillage (T₂) and (July 10) planting delay significantly increased the grain and stover yield, nutrient uptake, partial nutrient balance in nitrogen and phosphorus of pearl millet as replacement crop compared to other tillage treatments, but nutrient efficiency ratio no-tillage (T₁) and (July 30) planting delay significantly higher than other treatments.

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