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Influence of non-monetary inputs on growth dynamics, productivity and economics of semi *rabi* pearl millet (*Pennisetum glaucum* L.)

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Abstract
A field experiment was conducted at the College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat) to find out the response of pearl millet (*Pennisetum glaucum*) to sowing time, spacing and sowing method during semi *rabi* season in loamy sand soils found low in organic carbon and nitrogen, high in available phosphorus and potassium. There were 18 treatment combinations comprising of three levels, each of sowing times (30th August, 10th and 20th September) and spacing (30, 45 and 60 cm) and two levels of sowing methods (drilling and transplanting) embedded in a split-split plot design. Results revealed that sowing of semi *rabi* pearl millet (cv. GHB 558) at 45 cm row spacing by drilling on 10th September registered higher growth and yield attributing parameters *viz;* plant height, dry matter accumulation, dry matter translocation, dry matter translocation efficiency, contribution to pre-anthesis assimilates to grain, effective and total tillers per plant, length and girth of ear head, weight of grain per ear head and test weight. The same treatments produced significantly greater grain and fodder yields. Net return and BCR were also found higher in semi *rabi* pearl millet sown on 10th September by drilling at 45 cm spacing. In case of late (20th September) sowing of semi *rabi* pearl millet, sowing at 30 cm row spacing with drilling method compensated grain yield, straw yield, economic returns and BCR.

Keywords: Sowing time, spacing, sowing method, growth dynamics, pearl millet

Introduction

In India Pearl millet (*Pennisetum glaucum* L.) is fourth most important cereal crop after rice, wheat and sorghum. It has the greatest potential among all the millets. India has the largest area (7.90 million ha) with annual production of 9.18 million tonnes and productivity of 1154 kg/ ha. (Anon, 2016) [1]. Pearl millet cultivation is confined mainly during rainy season (*kharif*) across the country. Summer pearl millet is also popular in Gujarat with very high yield exceeding 4-5 tonnes/ha with excellent grain quality. In Maharashtra and Gujarat, pearl millet is also cultivated during *rabi* season (November-February) on a small scale. Though the crop favourably responds to better crop management both in *kharif* and *rabi* seasons, the erratic rainfall pattern of the south-west monsoon disturbed timely field operations of *kharif* season crop as well as during summer season heat stroke at flowering stage resulted in low production. In absence of any major environmental impediments in *rabi*, including absence of any major disease and insect-pest in this season, helps in realizing better profits from every additional unit of monetary inputs.

Under the failure of normal *kharif* crop due to erratic rainfall pattern, there is a need for alternate contingent crop that can be high yielding, fodder producing, moisture stress tolerant and short duration. Cultivation of semi *rabi* pearl millet is an alternative and new concept that has more prospects that can have all the qualities as a substitute contingent crop. Sowing time, spacing and sowing method are primary non-monetary inputs that improve productivity and profitability of any crop. Sowing at optimum time improves the production by providing suitable environment at all the growth stages. Timely sowing of crops generally ensures sufficient time for root development and vegetative growth and development for optimum harvesting of available soil nutrients and radiant energy (Soler *et al*., 2008) [24]. Generally, the duration for each growth stage is related to thermal time which is induced through different planting times by changing day length to a crop (Sanon *et al*., 2014) [21].

The effect of planting patterns on crop development is improved by the adjustment of row space. Plant spacing plays an important role on crop growth, phenological development and productivity of pearl millet.

Optimum intra and inter row spacing's confirm that plants grow properly with their above and below ground parts by exploiting more solar radiation and nutrients (Miah *et al*., 1990; Legwaila *et al*., 2014) [15, 12]. Intra and inter row spacing is one of the important components of systematic cultivation and manipulation, that could enhance productivity of pearl millet. The inter-row and intra-row distance can be varied depending on the method of sowing.

Direct seeding offers such advantages as faster and easier planting, reduced labour, earlier crop maturity by 7 to 10 days, more efficient water use and higher tolerance of water deficit and often higher profit in areas with an assured water supply. Transplanting increased the yield and also compensated the yield in case of delayed sowing time (Bhaskar, 1986) [2].

Transplanting of millet varieties grown in nurseries has also been shown to improve establishment in the field (Mapfumo, 2002) [13]. However, information related with such non-monetary inputs are not available, therefore, this experiment was planned with an objective to find out suitable date of sowing, spacing and method of sowing for semi *rabi* pearl millet.

Materials and method

A field experiment was conducted at the College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat) to find out the response of pearl millet (*Pennisetum glaucum*) to sowing time, spacing and sowing method during semi *rabi* season of the years 2016-17 and 2017-18 in loamy sand soils found low in organic carbon and available nitrogen, high in available phosphorus and potassium. The pearl millet variety GHB– 558 was taken for the present investigation.

The present experiment was conducted under split split design with four replications keeping three dates of sowing *viz*; 30th August (D_1), 10th September (D_2) and 20th September (D_3) as a main plot treatments, three row spacing *viz*; 30 cm (S_1), 45 cm (S_2) and 60 cm (S_3) as sub plot treatments and two methods of sowing *viz*; drilling (M_1) and transplanting (M_2) as sub-sub plot treatments. Seeding in the nursery was done on the same date on which drill sowing was done, and the seedlings were transplanted 20 DAS.

Thus, when drill sowing was done on 30th August, 10th September and 20th September, the crop was transplanted keeping 10 cm intra-row spacing on 20th September, 1st October and 11th October for D_1, D_2 and D_3 sowing dates, respectively. Out of the recommended dose of fertilizers (120 kg N + 60 kg P_2O_5) 50% nitrogen (60 kg N/ha) and 100% phosphorus (60 kg P_2O_5 /ha) was applied as basal and remaining 50% nitrogen (60 kg N /ha) was top dressed 30 DAS/DATP. Gap filling and thinning operations for drill sown pearl millet were performed accordingly to maintain uniform plant population. All other common agronomical operations were carried out as per the requirements for all the treatments.

Observations pertaining to all the growth and yield attributing parameters were recorded during various growth stages. Efforts were also made to study the effect of different dates of sowing, spacings and methods of sowing on the dry matter translocation, dry matter translocation efficiency as well as contribution of pre-anthesis assimilates to grain as per the following formulae:

1. **Dry matter translocation (g/m^2)**

   = Dry matter at grain filling – (leaves + stem + ear husk) Dry matter at maturity

2. **Dry matter translocation efficiency (%)**

$$= \frac{Dry\ matter\ translocation}{Dry\ matter\ at\ grain\ filling} \times 100$$

3. **Contribution of pre-anthesis assimilates to grain (%)**

$$= \frac{Dry\ matter\ translocation}{Grain\ yield/plant} \times 100$$

Economics concerning to gross income, net realization and Benefit Cost Ratio (BCR) were calculated based on recent prices of grain and fodder prices of pearl millet. BCR was calculated using following formula:

$$BCR = \frac{Gross\ Income}{Gross\ Expenditure}$$

Result and Discussion

Growth dynamics

Growth and development of crop depend on the progressive initiation of organ primordial, cell differentiation and expansion of component cells until characteristics form of the plant is realized. Pooled data over 2 years manifested in Table 1 and 2 revealed that all the growth parameters and yield attributes of semi *rabi* pearl millet *viz*; Plant height (cm), dry matter accumulation (g/m^2), dry matter translocation(g/m^2), dry matter translocation efficiency (%), contribution of pre-anthesis assimilates to grain (%), effective and non-effective tillers, total number of tillers per meter row length, ear head length and girth (cm), weight of grain per ear head (g) and test weight (g) had differential responses to sowing time, spacing and sowing method.

Table 1: Influence of time of sowing, spacing and method of sowing on Growth parameters of *rabi* pearl millet at different growth stages (Pooled over 2 years)

Treatments	Plant height (cm)			Dry matter (g/m^2)				Dry matter translocation (g/m^2)
	45 DAS/ DATP	60 DAS/ DATP	Harvest	45 DAS/ DATP	60 DAS/ DATP	75 DAS/ DATP	Harvest	Harvest
Main Plot (Date of sowing) (D)								
D_1: 30th August	63.48	117.2	162.7	790	1669	2104	2269	294
D_2: 10th September	74.75	133.3	186.1	852	1992	2539	2554	384
D_3: 20th September	66.13	124.9	169.0	817	1792	2269	2324	347
S.Em±	1.36	2.11	2.65	10.30	20.63	20.28	20.69	5.82
C. D. at 5%	4.19	6.51	8.2	32	64	63	64	18

C. V. (%)	13.83	11.70	10.65	8.70	7.86	6.10	6.02	11.81
Sub Plot (Spacing) (S)								
S_1:30 cm	68.55	125.7	172.9	866	1903	2398	2484	381
S_2: 45 cm	73.12	129.7	179.0	872	1988	2542	2587	394
S_3: 60 cm	62.68	119.9	166.0	721	1562	1972	2075	251
S.Em±	1.33	1.16	1.56	9.10	15.05	19.39	21.06	6.20
C. D. at 5%	3.82	3.34	4.5	26	43	56	61	18
C. V. (%)	13.51	6.45	6.25	7.69	5.74	5.83	6.12	12.57
Sub Sub Plot (Method of sowing) (M)								
M_1: Drilling	72.99	132.0	182.0	839	1903	2426	2469	369
M_2: Transplanting	63.25	118.2	163.3	801	1733	2182	2296	314
S.Em±	0.76	1.06	1.78	5.76	12.01	14.60	15.09	5.00
C. D. at 5%	2.15	2.99	5.0	16	34	41	43	14
C. V. (%)	9.47	7.17	8.76	5.96	5.61	5.38	5.38	12.41

Table 2: Influence of time of sowing, spacing and method of sowing on Growth parameters of *rabi* pearl millet at harvest (Pooled over 2 years)

Treatments	Dry matter translocation efficiency (%)	Contribution of pre-anthesis assimilates to grain (%)	Effective tillers	Non-effective tillers	Total number of tillers per meter row length	Ear head length (cm)	Ear head girth (cm)	Weight of grain per ear head (g)	Test weight (g)
Main Plot (Date of sowing) (D)									
D_1: 30^{th} August	13.67	8.46	12.46	6.96	19.42	18.81	9.25	15.01	10.33
D_2: 10^{th} September	16.75	11.54	15.00	6.26	21.63	21.12	10.14	16.38	11.16
D_3: 20^{th} September	16.20	9.88	14.31	6.75	21.06	19.94	9.26	15.59	10.73
S.Em±	0.28	0.18	0.21	0.11	0.26	0.25	0.13	0.19	0.10
C. D. at 5%	0.87	0.56	0.66	NS	0.80	0.78	0.40	0.57	0.31
C. V. (%)	12.57	12.66	10.65	11.40	8.70	8.83	9.21	8.17	6.52
Sub Plot (Spacing) (S)									
S_1:30 cm	15.86	10.35	13.88	6.71	20.58	19.77	9.62	15.55	10.78
S_2: 45 cm	16.63	10.84	14.90	6.90	21.79	21.05	9.90	16.43	11.13
S_3: 60 cm	14.13	8.70	13.00	6.73	19.73	19.06	9.40	15.00	10.31
S.Em±	0.25	0.19	0.13	0.13	0.19	0.28	0.08	0.24	0.14
C. D. at 5%	0.71	0.54	0.38	NS	0.53	0.81	0.23	0.68	0.41
C. V. (%)	10.95	13.12	6.53	13.01	6.22	9.83	5.81	10.53	9.17
Sub Sub Plot (Method of sowing) (M)									
M_1: Drilling	16.17	10.37	14.96	6.13	21.08	20.75	10.01	16.26	11.09
M_2: Transplanting	14.91	9.55	12.89	7.43	20.31	19.17	9.26	15.07	10.40
S.Em±	0.21	0.16	0.13	0.10	0.16	0.22	0.08	0.18	0.14
C. D. at 5%	0.59	0.45	0.38	0.29	0.46	0.62	0.21	0.51	0.39
C. V. (%)	11.30	13.44	8.18	12.66	6.62	9.38	6.58	9.70	10.86

Effect of sowing time

Plant height of pearl millet increased progressively with advance in age of the crop up to harvest wherein, different treatments exerted their significant effect on plant height measured at 45, 60 DAS/DATP and at harvest. Significantly the highest plant height at 45 DAS/DATP (74.75cm), 60 DAS/ DATP (133.3 cm) and at harvest (186.1 cm) on pooled basis was reported under D_2 (10th September) sowing. However, it was found at par with D_3 (20th September) on pooled basis (124.9 cm) at 60 DAS/DATP. The higher value of plant height in D_2 sowing over early and delayed ones could be attributed to availability of optimum environmental conditions which might enhance accumulation of photosynthates from source to sink (Detroja *et al.*, 2018, and Siddig *et al*., 2013) [8, 22].

Dry matter production of plant would be more meaningful criterion for assessing complete vegetative growth. Results on periodically recorded plant dry matter accumulation at 45, 60, 75 DAS/DATP and at harvest on pooled basis indicated that statistically highest plant dry matter accumulation (852 g/m^2) was recorded under the treatment D_2 (10th September) at 45 DAS/DATP. Significantly the highest dry matter accumulation was registered in D_2 (10^{th} September) in pooled analysis at 60, 75 DAS/ DATP and at harvest with 1992, 2539 and 2554 g/m^2, respectively. Pearl millet sown on 30^{th} August (D_1) recorded significantly the lowest dry matter accumulation. Dry matter translocation (384 g/m^2), dry matter translocation efficiency (16.75%) and contribution of pre-anthesis assimilates to grain at harvest (11.54%) was noted significantly highest in treatment D_2 (10^{th} September), However, dry matter translocation efficiency (16.20%) was found at par with D_3 (20^{th} September). Contrarily, significantly the lowest above attributes were observed in D_1 (30^{th} August) treatment on pooled basis. The higher dry matter production and its resultant effects on its translocation and contribution to pre-anthesis assimilates in grain in treatment D_2 (10^{th} September) might be because of timely sown crop may enjoy favourable climatic condition in terms of temperature and other climatic parameters during various crop growth stages, which might be reflected into better growth. Due to suitable environment, there might be an increase in plant vigour in terms of height, leaf area index, higher photosynthetic area and better interception of solar radiation with better utilization of available resources, and thereby increased synthesis of carbohydrate and production of more dry matter production of plant per unit area, dry matter translocation, dry matter translocation efficiency and contribution of pre-anthesis assimilates to grain. Almost similar results were reported by Maurya *et al*., (2016) [14], Chauhan *et al*., (2015) [5] and Deshmukh and Patel (2013) [6].

The sowing date had significant effect on number of effective tillers and total number of tillers per meter row length recorded at harvest. Among different sowing time treatments, treatment D_2 (10^{th} September) registered significantly higher number of effective tillers (15.00) and total number of tillers per meter row length (21.63), being statistically at par with treatment D_3 (20th September) on pooled basis. Significantly the lowest value of number of effective tillers and total number of tillers per meter row length were recorded under treatment D_1 (30th August). Number of non-effective tillers per meter row length was found non-significant in pooled analysis. Treatment D_2 (10th September) registered significantly the highest values for length (21.12 cm) and girth (10.14 cm) of ear head, grain weight per ear head (16.38 g.) and test weight (11.16 g) on pooled basis. In contrast, significantly the lowest values of these yield attributes were observed under treatment D_1 (30th August). Pearl millet sown on 10th September (D_2) produced the higher value of effective tillers per meter row length in case of optimum sowing over early and delayed ones could be attributed to availability of optimum environmental conditions in term of temperature and other climatic parameters during various crop growth stages, which might enhance accumulation of photosynthates from source to sink which might be reflected into better growth and development of crop. The results were in conformity with Detroja *et al*., (2018) [8], Chauhan *et al*., (2015) [5] and Deshmukh *et al*., (2014) [6]. Moreover, the crop sown on 10th September (D_2) exposed to congenial weather condition like considerably higher absorption of photosynthetically active radiation (PAR) resulting in higher light use efficiency (LUE) which ultimately increased photosynthetic rate, CO_2 concentration, stomatal conductance and significant improvement in important growth attributes *viz*., plant height, number of effective tillers, leaf area and dry matter production (Wankhede *et al*., 2018) [26].

Effect of spacing

Pearl millet sown at 45 cm (S_2) row spacing recorded significantly the highest plant height of 73.12, 129.7 and 179.0 cm at 45, 60 DAS/DATP and at harvest, respectively on pooled basis. This treatment also registered significantly the highest day matter accumulation (872, 1988, 2542 and 2587 g/m^2, respectively) in pooled analysis at 45, 60, 75 DAS/DATP and also at harvest. At 45 DAS/DATP it was statistically similar with S_1 (30 cm) treatment (866 g/m^2) in pooled analysis. Pearl millet sown at 60 cm (S_2) row spacing recorded significantly the lowest dry matter in pooled analysis at 45, 60, 75 DAS/DATP and also at harvest.

Significantly the maximum dry matter translocation (394 g/m^2), dry matter translocation efficiency (16.75%) and contribution of pre-anthesis assimilates to grain (11.54%) were observed in S_2 (45 cm) treatment, which was statistically at par with S_1 (30 cm) treatment for dry matter translocation (381 g/m^2) in pooled analysis. All the above parameters recorded significantly minimum when pearl millet sown at 60 cm (S_3) row spacing. The significant increase in dry matter at successive growth stages and its resultant impact on its translocation, translocation efficiency and contribution to pre-anthesis assimilates to grain seems to be on account of larger canopy development due to higher plant height under S_2 (45 cm) treatment. The highest dry matter accumulation reported in crop sown with 45 cm spacing could be attributed to the fact that proper spacing availed ideal space, moisture, nutrients and sun light. It might have accelerated the synthesis of more chlorophyll and amino acids and stimulated the cellular activity, which is useful for the process of cell division, meristematic growth coupled with cell enlargement, resulting in production of large leaves which ultimately leads to higher dry matter accumulation. These results were confirmed with those reported by Radhakumari *et al.*, (2018) [17].

Row spacing had significant effect on number of effective tillers and total number of tillers per meter row length recorded at harvest on pooled basis. (Table2). Among different spacing treatments, treatment S_2 (45 cm) registered significantly highest number of effective tillers (14.90) and total number of tillers per meter row length (21.79) in pooled analysis. Length (21.05 cm) and girth of ear head (9.90 cm), grain weight per ear head (16.43 g) and test weight (11.13 g) were noted significantly the highest in S_2 (45 cm) treatment. Test weight (10.78 g) was found statistically at par with S_1 (30 cm) treatment on pooled basis. Significantly the lowest length and girth of ear head, grain weight per ear head and test weight were observed in S_3 (60 cm) treatment. This could be as a result of adequate space provided by wider spacing which enables the plants to effectively utilize the available resources (light, moisture and soil nutrients) for tiller formation. Proper crop geometry facilitates sufficient interception of sunlight and satisfactory absorption of nutrients and water from the soil due to proper development of root system. Crop sown with 30 cm (S_1) and 60 cm (S_3) produce comparatively less tillers per meter row length. It may be due to increased evaporation with increased row spacing and increased transpiration with decreased row spacing. These results are in line with what were reported by Bhunia *et al.*, (2015) [3] and Saba *et al.*, (2015) [19].

Effect of method of sowing

In pooled analysis plant height was found significantly higher when pearl millet sown with M_1 (drilling method) at 45 (72.99 cm) and 60 DAS/DATP (132.0 cm) and at harvest (182.0 cm). Transplanting gave significantly the lower plant height might be due to greater transfer of photosynthates from vegetative source of reproductive sink. In drilling method, crop was not disturbed after germination, which might be the probable reason on increase periodical plant height as compare to transplanted crop. The results are in conformity with those reported by Lakhani *et al.* (2014) [11]. Similarly periodical dry matter accumulation at 45, 60, 75 DAS/DATP and at harvest was recorded significantly superior in M_1 (drilling) treatment (839, 1903, 2426 and 2469 g/m^2, respectively). Dry matter translocation (369 g/m^2), dry matter translocation efficiency (16.17%) and contribution of pre-anthesis assimilates to grain (10.37%) were also observed significantly greater in M_1 (drilling) treatment.

Number of effective tillers (14.96) and total number of tillers per meter row length of pearl millet (21.08) were also registered significantly higher value in M_1 (drilling) treatment on pooled basis. Totally opposite observation was noted in case of non-effective tillers per meter row length. Significantly higher number of non-effective tillers noted in M_2 (transplanting) treatment, while significantly lower number of non-effective tillers in M_1 (drilling) treatment. This might be due to more vegetative growth resulting from efficient utilization of nutrients, water, radiation and increased metabolic activities followed by increased translocation towards above mentioned yield contributing characters under drilling method of sowing. The results are in contradictory with the resulted reported by Lakhani *et al*., (2014) [11] and Rathore *et al*., (2006) [18].

Among different sowing methods, significantly higher ear head length (20.75 cm) and girth (10.01 cm), grain weight per ear head (16.26 g) and test weight (11.09 g) were registered in M_1 (drilling) treatment on pooled basis. This could be the effect of transplanting shock. When plants are transplanted, mechanical injuries occurred to the roots and a time taken for adaptation to the new environment slowed down the process of assimilation and thereby growth. This might delay vegetative growth resulting from effective utilization of nutrients, water, radiation and reduced metabolic activities followed by decreasing translocation towards length of ear head under transplanting method of sowing. Similar results were recorded by Patil *et al*., (2014) [16] and Rathore *et al*., (2006) [18].

Productivity

Effect of sowing

A perusal of data presented in Table 3 stated that different sowing time had exerted significant influence upon grain and fodder yield of semi *rabi* pearl millet during both the years of experimentation as well as on pooled basis. Treatment D_2 (10th September) registered significantly the highest grain yield of 2599, 2709 and 2654 kg/ ha during first and second year of experiment as well as in pooled analysis, respectively, which was found 14.3 and 22.1 per cent, 16.8 and 27.1 per cent and 14.6 and 24.7 per cent higher yield respectively over D_3 and D_1 during 2016-17, 2017-18 and in pooled analysis, respectively. The data further indicated that significantly highest fodder yield worth 6912, 6982 and 6947 kg /ha was produced under treatment D_2 (10th September) during 2016-17, 2017-18 and in pooled analysis, respectively, which was found at par with sowing of pearl millet on 20th September (D_3) (6449 kg/ ha) during second year of experimentation (2017-18). Treatment D_2 gave 9.0 and 10.8 per cent, 8.3 and 12.2 per cent and 8.6 and 11.5 per cent higher fodder yield over D_3 and D_1, respectively during 2016-17, 2017-18 and in pooled analysis, respectively. Yield of crop is a complex function of metabolic and bio-chemical processes taking place in a plant system which may be modified by the environment and the suitable cultural practices adopted in the cultivation of the crop. The significant improvement in grain and fodder yield of pearl millet crop sown on 10th September was attributed to the congenial microclimatic conditions *viz.*, absorbed photosynthetically active radiation, significant increase in growth attributes viz., number of effective tillers and dry matter accumulation and important yield contributing characters *viz.*, ear head length and girth, grain weight per ear head and test weight. Further, this increase in grain yield might be attributed to more accumulation of nutrients and essential elements from soil. Delayed sowing hastened the crop's phonological development, thereby, causing significant reduction in crop yields. These results are in conformity with findings of Bhuva and Detroja (2018) [4] and Detroja *et al*., (2018) [8].

Effect of spacing

Data presented in Table 3 further revealed that treatment S_2 (45 cm) out yielded other spacing with 2540, 2690 and 2615 kg/ ha grain yield during 2016-17, 2017-18 and in pooled analysis, respectively, which was found 8.0 and 20.5 per cent higher during first year, 13.6 and 28.0 per cent higher during second year and 10.8 and 24.2 per cent higher in pooled analysis over S_1 (30 cm) and S_3 (60 cm), respectively. The same trend was observed for fodder yield and pearl millet sown with 45 cm (S_2) row spacing registered significantly the highest fodder yield ranking 6833, 6843 and 6838 kg/ ha during first and second year of experiment and on pooled analysis, respectively. However, it was found statistically at par with 30 cm (S_1) row spacing during both the year of experimentation. Treatment S_2 (45 cm) produced 6.5, 5.7 and 6.1 per cent and 9.5, 8.0 and 8.7 per cent higher fodder yield during first and second year of experiment and in pooled analysis, respectively over S_1 (30 cm) and S_3 (60 cm), respectively. The improvement in the yield performance of individual plant at lower (30 cm) plant density or wider (60 cm) row spacing failed to compensate for the increased number of plants per unit area at ideally higher plant density or ideally narrows (30 cm) row spacing. Similar results were reported by Lakew and Barhenu (2019) [10], Singh *et al.*, (2019) [23], Sangeetha and Surakod (2018) [20], Radhakumari *et al.*, (2018) [17] and Katiyar *et al.*, (2017) [9].

Effect of method of sowing

With respect to different sowing methods of pearl millet (Table 3), treatment M_1 (drilling) produced significantly higher grain yield of 2509, 2593 and 2551 kg /ha during first and second year of experimentation and in pooled analysis, respectively, as compared to treatment M_2 (transplanting). During first and second year and in pooled analysis 16.3, 18.9 and 17.6 per cent higher grain yield was produced under Drilling method of sowing (M_1), respectively, over transplanted method of crop establishment. The increase in grain yield might be due to favourable effect of dry matter accumulation, number of effective tillers, higher length and girth of ear head, more weight of grains per ear head and higher test weight. The results summarized in Table 4, revealed that significantly higher fodder yield of 6864, 6891 and 6877 / ha was recorded during 2016-17, 2017-18 and in pooled analysis, respectively under drilling method of sowing (M_1) over transplanting (M2) treatment. Transplanting (M_2) treatment observed significantly lower fodder yield of 6131, 6213 and 6172 kg/ ha during first and second season and on pooled analysis basis, respectively.

Drilling method (M_1) registered 12.0, 10.9 and 11.4 per cent higher fodder yield over transplanting (M_2) treatment. Significantly higher fodder yield recorded under drilling method of sowing might be due to its favourable effect on growth characters viz., leaf area index, dry matter accumulation and total number of tillers per plant. The effect of drilling method of crop establishment method on fodder yield can also be explained on the basis that pearl millet sown with drilling method tended to produce more vegetative growth resulting from efficient utilization of nutrients, water, radiation and increased metabolic activities followed by increased translocation towards above mentioned growth attributing characters which might have led to significant increase in straw yield. Lakhani *et al.*, (2014) [11], Patil *et al.*, (2014) [16] and Upadhyay *et al.*, (2001) [25], reported contradictory results for *kharif* and summer cultivation.

Interaction effects

Interaction effect of D X S was found significant for grain yield for the year 2016-17 and in pooled results. Data given in Tables 3.1 to 3.3 revealed that D_2S_2 out yielded all the treatment combinations with 2932 kg/ha and 3042 kg/ha grain yield during 2016-17 and in pooled analysis, respectively. Treatment combination D_2M_1 produced significantly highr grain yield for the year 2017-18 (3067 kg/ha) and in pooled (2951 kg/ha). Treatment combination S_2M_1 also produced significantly highest grain yield (2986 kg/ha) over rest of the treatment combinations on pooled basis. As far as fodder yield was concerned, treatment combination D_2M_1 produced significantly highest fodder yield during 2016-17 (7452 kg/ha), 2017-18(7713 kg/ha) and in poo analysis (7586 kg/ha) over rest of the treatment combinations.

Table 3: Influence of time of sowing, spacing and method of sowing on grain yield and fodder yield of *rabi* pearl millet at harvest

Treatments	Grain yield (kg / ha)			Fodder yield (kg / ha)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Main Plot (Date of sowing) (D)						
D_1: 30th August	2128	2131	2129	6239	6225	6232
D_2: 10th September	2599	2709	2654	6912	6982	6947
D_3: 20th September	2273	2319	2296	6343	6449	6396
S.Em. ±	31.19	31.91	22.31	116.9	154.0	96.67
C. D. at 5%	108	111	69	405	534	298
C. V. (%)	6.55	6.55	6.55	8.81	11.52	10.26
Sub Plot (Spacing) (S)						
S_1:30 cm	2352	2367	2360	6417	6477	6447
S_2: 45 cm	2540	2690	2615	6833	6843	6838
S_3: 60 cm	2108	2102	2105	6243	6336	6289
S.Em. ±	32.42	61.52	34.77	156.1	130.5	101.7
C. D. at 5%	96	183	100	464	388	292
C. V. (%)	6.81	12.63	10.21	11.77	9.76	10.80
Sub Sub Plot (Method of sowing) (M)						
M_1: Drilling	2509	2593	2551	6864	6891	6877
M_2: Transplanting	2158	2180	2169	6131	6213	6172
S.Em ±	30.73	36.45	23.84	74.07	78.95	54.13
C. D. at 5%	89	106	67	215	229	153
C. V. (%)	7.90	9.17	8.57	6.84	7.23	7.04
Interaction effects						
D X S	Sig.	NS	Sig.	NS	NS	NS
D X M	NS	Sig.	Sig.	Sig.	Sig.	Sig.
S X M	NS	Sig.	NS	NS	NS	NS
D X S X M	NS	NS	NS	NS	NS	NS

Table 3.1: Interaction effect of D x S on grain yield of *semi* rabi pearl millet at harvest

Treat.	Grain yield (kg/ ha)					
	2016-17			Pooled		
	S_1	S_2	S_3	S_1	S_2	S_3
D_1	2226	2280	1878	2274	2281	1833
D_2	2565	2932	2302	2554	3042	2367
D_3	2267	2408	2144	2251	2524	2114
S.Em ±	56.15			60.22		
C. D. at 5%	167			173		

Table 3.2: Interaction effect of D x M and S x M on grain yield of *semi* rabi pearl millet at harvest

Treatments	Grain yield (kg / ha)						
	2017-18		Pooled			2017-18	
	M_1	M_2	M_1	M_2		M_1	M_2
D_1	2278	1983	2279	1980	S_1	2586	2148
D_2	3067	2352	2951	2358	S_2	2986	2395
D_3	2434	2205	2423	2169	S_3	2206	1997
S.Em ±	63.14		41.29		S.Em ±	63.14	
C. D. at 5%	183		117		C. D. at 5%	106	

Table 3.3: Interaction effect of D x M on fodder yield of *semi* rabi pearl millet at harvest

Treatments	Fodder yield (kg / ha)					
	2017-18		2017-18		Pooled	
	M_1	M_2	M_1	M_2	M_1	M_2
D_1	6454	6023	6426	6023	6440	6023
D_2	7458	6366	7713	6250	7586	6308
D_3	6681	6005	6533	6366	6607	6185
S.Em ±	128.3		136.7		93.75	
C. D. at 5%	372		396		265	

Economics

Data pertaining to combined effect of sowing time, spacing and method of sowing on total income, net realization and BCR presented in Table 4 showed that the highest net return worth `. 50877 /ha was secured under treatment combination $D_2S_2M_1$ (10th September + 45 cm + drilling) with highest BCR of 2.97. The treatment combination $D_2S_1M_1$ (10th September + 30 cm + drilling) was found the next best treatment combination with respect to net profit of `. 38028 / ha and BCR of 2.35. In case of delayed sowing at 20th September, rabi pearl millet drilled at 30 cm spacing obtained higher net realization (` 34014 / ha) and BCR (2.31).

Table 4: Influence of different treatment combinations on economics of semi *rabi* pearl millet (Average of two years)

Treatments	Yield (kg/ ha)		Gross realization (/ha)	Cost of cultivation (/ha)	Net realization (/ha)	B:C
	Grain	Fodder				
$D_1S_1M_1$	2348	6194	56575	25976	30599	2.18
$D_1S_1M_2$	2104	5778	51265	29692	21573	1.73
$D_1S_2M_1$	2460	6861	60203	25779	34424	2.34
$D_1S_2M_2$	2100	6653	53383	29495	23888	1.81
$D_1S_3M_1$	2031	6306	51308	25583	25725	2.01
$D_1S_3M_2$	1725	5639	44285	29298	14987	1.51
$D_2S_1M_1$	2750	7250	66250	28231	38019	2.35
$D_2S_1M_2$	2379	6167	57050	29692	27358	1.92
$D_2S_2M_1$	3222	8111	76663	25779	50884	2.97
$D_2S_2M_2$	2642	7028	63805	29495	34310	2.16
$D_2S_3M_1$	2534	7014	61880	25583	36297	2.42
$D_2S_3M_2$	2069	5903	50965	29298	21667	1.74
$D_3S_1M_1$	2424	7028	59990	25976	34014	2.31
$D_3S_1M_2$	2109	6083	52115	29692	22423	1.76
$D_3S_2M_1$	2489	6319	59355	25779	33576	2.30
$D_3S_2M_2$	2328	6028	55810	29495	26315	1.89
$D_3S_3M_1$	2325	6694	57423	25583	31840	2.24
$D_3S_3M_2$	1963	5903	49110	29298	19812	1.68

Selling Price (`./ kg): Grain 17.50, Dry Fodder: 2.50

Conclusion

In light of above result and discussion, it can be concluded that, sowing of semi *rabi* pearl millet (cv. GHB 558) at 45 cm row spacing by drilling on 10th September produced higher grain and fodder yields. Net return and BCR were also higher in semi *rabi* pearl millet sown on 10th September by drilling at 45 cm spacing. In case of delayed (20th September) sowing of semi *rabi* pearl millet, sowing at 30 cm row spacing with drilling method, compensated grain yield, fodder yield, economic returns and BCR.

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