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Research Article

The impact of sowing time and plant spacing on growth and productivity of pearl millet under semi-arid environment

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ABSTRACT

Optimum sowing time and plant density in terms of plant spacing are the most important management options to get higher yield of any crop. To optimize planting time and plant spacing for better growth and yield of pearl millet, a field study was conducted to study the impact of sowing time and plant spacing on growth and productivity of pearl millet under semi-arid environment. The study comprised of two sowing dates, i.e. June-20-2015 and July-06-2015 with three planting densities (10 cm spacing, 15 cm spacing and 20 cm plant to plant spacing). Randomized complete block design with split plot arrangements was used by keeping sowing dates in main plots and planting densities in subplots. The millet hybrid 86M86 was sown with help of single row hand drill and row to row distance was 45 cm. All agronomic practices were kept normal and uniform for all treatments under study. It was observed that grain weight per panicle, panicle length, panicle girth, 1000-grain weight (g), grain yield (t ha-1) and biological yield (t ha-1) increased in sowing time 20-June-2015 with 15 cm plant to plant distance. The maximum value of these parameters was observed in sowing time 20-June-2015 with 15 cm plant spacing.

Keywords: Pearl millet, Plant spacing, Productivity, Growth, Sowing time.

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Introduction

Pearl millet is the sixth most valuable cereal in the world after wheat, rice, maize, sorghum and barley (Singh *et al.*, 2003). People in dry and hot areas are highly dependent on pearl millet for their food purpose. Millet has got attention of researchers and farmers in last few decades because it has the ability to grow in marginal lands where other crops failed to grow. Pearl millet is known for its high tolerance against abiotic stresses like, drought stress, heat stress and salt stress as compared to other cereals. It has its significant importance because of a good source of grains and fodder in the hot season of the year (Khattak *et al.*, 2011). Being a low input and high nutritious cereal crop, it has significant importance in food security and malnutrition. As food, millets are nutritionally equivalent or superior to most cereals; containing high levels of methionine, cysteine, and other vital amino acids for human health. In the world, total area under pearl millet production was 28 million hectares that gave total production of 21.8 million hectares (FAO, 2014-15). Pearl millet is a crop that is successfully grown in the dry region of South Asia and Africa (Baltensperger, 2002). In Pakistan, the total area under pearl millet cultivation was 486 thousand hectares. Pakistan produced 299 thousand tons of pearl millet in a year (Govt. of Pakistan, 2016). This production is low as in our neighbors they are ranked 1st in millet production and we have same environment. We are only lacking in research and famers preferences. In case of pearl millet, the time of sowing is usually recommended on the bases of different factors especially soil temperature (Andrews *et al*., 1998). Actually, pearl millet is a short day plant that completes its reproductive phase in short day length and its flowering is delayed when exposed to longer day (Uzoma *et al.*, 2010). Optimum plating time plays an important role in the growth and development of pearl millet crop. Plantation at optimum time allows the maximum root development of the crop and healthy root shoot growth to for proper harvesting of available resources like solar energy, soil moisture and nutrition (Soler et al., 2007). Results of an experiment has shown that if pearl millet variety Drsma is sown early in the season then it will face an attack of foliage disease which causes 41% of losses. In the same experiment, it has been observed that late sown pearl millet variety was infested by North Darfur Dembi which causes 30.9% losses in total yield (Kamal *et al.*, 2013). Planting time and plant spacing are the important factors that can determine the proper plant population through balancing the inter plant competition that will ultimately affect the final product (Nakano and Morita, 2009). They also stated that over population than normal/recommended works as an obstacle in performing intercultural practices. The inter plant competition will be very high for the resources like, sunlight, air and nutrients in case of high population which will definitely results in diseases, lodging, mutual shading. All these factors will enhance the straw yield as compare to the grain yield (Bhowmik*et al.*, 2012). In pearl millet if plant spacing is more this will lead towards more leaf area and leaf area index. This results in more fresh weight and more dry weight (Yarnia, 2010). Almass *et al.*, (2007) Results of an experiment have shown that in pearl millet the grain yield is high where spacing is 0.04 m as compared to those where spacing is 0.09 m because in row spacing 0.04m there are more number of plants per unit area and less in case of 0.09 m and yield of an individual plant is also less in area of spacing 0.04. Number of plants in a field is a management variable that can affect the yield and quality of many crops (Kamal *et al.*, 2013).

The objective of this study was to check the response of pearl millet in semi-arid region of Pakistan and optimization of sowing date and plant spacing to get higher productivity of hybrid pearl millet. As well as to evaluate growth, phenology and yield responses of hybrid pearl millet under semi-arid environment

Materials And Methods

A field experiment was conducted at Agronomic Research Area, University of Agriculture Faisalabad which is It is situated between latitude 30 and 31.5 North, longitude 73 and 74 East. The experiment was done to study the effects of different sowing dates and planting density on hybrid pearl millet. The experiment was laid out in Randomized Complete Block Design (RCBD) under split plot arrangement having three replications. Sowing dates were kept in the main plots and plant spacing in sub plots. The distance between row to row and plant to plant was maintained 0.45 m and 0.1 m, 0.15 m, 0.20 m respectively. The crop was sown with the help of single row hand drill in an area of 6 m × 3.6 m. The experiment was comprised of following treatments: factor A was comprised of two sowing dates which are (SD_1: June-20-2015 and SD_2: July-06-2015) and factor B was three different plant spacing's (PS_1: 10 cm, PS_2: 15 cm and PS_3: 20 cm).

Table 1: Results of soil analysis

Parameter	Depth (cm)	pH	EC (dSm"1)	N (%)	P_2O_5 (ppm)	K2O (ppm)	Organic Matter	Sand (%)	Silt (%)	Clay (%)
Values	0-15	8.2	4.4	0.061	18.5	280	1.26	20	17	63
	15-30	8.4	4.6	0.058	14.7	240	1.19	19	16	65

Crop Husbandry

The land was prepared by two ploughings, each followed by planking with the help of a tractor drawn cultivar to achieve the normal seed bed. Recommended seed rate for hybrid pearl millet (86M86) was 6.25 kg ha^{-1}. There were two sowing times, 1st sowing was done on 3rd week of June and 2nd sowing was done on 1st week of July. The crop was sown under line sowing with hand drill having 45 cm of row to row distance. Basic dose of potassium sulfate and triple super phosphate were incorporated in the soil (5 cm depth) at 17-06-2015 and 04-07-2015 for 1st and 2nd sowing dates, respectively. Urea fertilizer was applied after irrigation in three different splits. Three irrigations were applied including one roni of 4 mm and two irrigations of 3 mm were applied at 16-07-2015 and 30-08-2015 respectively. The crop was harvested at full physiological maturity. A one-meter-long row was harvested from each plot at fifteen days' interval. Fresh and dry weights of each part of plant (leaf, stem and Panicle) were determined. A sub-sample of each part of plant was oven dried at 70°C till a constant weight. Total dry matter (TDM) was attained by summing weights of all the components. Leaf area meter was used to record leaf area. From the measurements of leaf area and dry weights different parameters can be calculated.

Crop Development

In both sowing times I have selected one square meter area for the emergence count. Then five plants were selected at random from each plot for recording the development events, such as, flowering and maturity. The same tagged plants in each plot were kept under observation and their date of 50% flowering and mean days to flowering will be worked out from date of sowing. Leaf area index (LAI) was calculated as the ratio of leaf area to land area (Watson, 1952). Leaf area is recorded with the help of image J software. Leaf area duration (LAD) for each sampling date was estimated according to (Hunt, 1978) $LAD = (LAI_1+LAI_2) \times (T_2 - T_1) / 2$. Where LAI_1 and LAI_2 were the leaf area indices at time T_1 and T_2 respectively. Cumulative LAD at final harvest was calculated by adding all LADs values. It is the biomass in terms of dry matter accumulated by crop in a specific period. To get total dry matter, the sub-sample was sun dried for two to three days and placed in oven at 70 ºC for three days or until the sample gets a constant weight. Crop growth rate was calculated as proposed by (Hunt, 1978) at each sampling date CGR = (W_2-W_1) / (T_2- T_1). Where W_1 and W_2 will be, the total dry weights harvested at times T_1 and T_2 respectively. Mean CGR was calculated by taking average of all CGRs calculated at each destructive harvest. The mean net assimilation rate (NAR) was predicted by using the formula of (Hunt, 1978) NAR = TDM / LAD. TDM and LAD are the total dry matter and leaf area duration at final harvest, respectively. Three plants were tagged from each plot randomly to record the different developmental events, such as flowering, panicle initiation and maturity. The collected data was analyzed statistically by using the Fisher analysis of variance technique (Steel, 1997) and treatments' means were compared by using least significant difference test at 5% level of probability.

Results

Plant height is generally measured by vegetative growth of plant. This growth of plant is not only affected by genetic variability of the cultivar but also significantly influenced by environmental factors. Effect of plant spacing for plant height was recorded non-significant. The effect of sowing time on plant height was significant as shown in the table 2. The maximum plant height was observed in sowing time 1 that was (185.32 cm) followed by sowing time 2 that gave plant height of (143.26 cm). The reason behind these results was that the early sown crop has got more degree days to complete its growth and development which results is maximum utilization of the assimilates to produce more plant height as compared to late sown pearl millet. Almost same results were reported by (Maas *et al*., 2007) that pearl millet which was sown in June gave taller plants as compared to late sown pearl millet which was sown in July. The height of plants increase in June as day length is also long as compared to late sown crop. So, the duration of vegetative period of the pearl millet has significant effect on the dry matter and it also affects the main shoot (Craufurd *et al.,* 1988).

Growth Parameters

Leaf area index was smoothly increased and reached to its maximum value at almost 69 DAS for both the sowing dates; therefore, leaf area index was declined to minimum at almost 91 DAS. Data in the table 2 showed that planting time 1 and planting time 2 was non-significant for leaf area index (LAI) in the pearl millet. Data in the table 3 showed that leaf area index (LAI) was significantly affected by different planting densities (10 cm, 15 cm and 20cm). Leaf area index (LAI) was observed maximum in planting density (15 cm) with value of (6.2591) and the minimum leaf area index (LAI) was observed in planting density (20 cm) with value of 5.8818. The effect of interaction of planting time and plant spacing on leaf area index (LAI) was non-significant. Eshraghi *et al* (2013) has stated that sowing time has significant effect on the leaf area index which is same as I reported in my work.

Table 3 indicated that sowing time has significant effect on leaf area duration in pearl millet. We can see that sowing time 1 has the leaf area duration (348.14) followed by sowing time 2 that gave a value (271.05). The effect of plant spacing on leaf area duration was highly significant. The maximum leaf area duration (319.54) was observed in plant spacing (15 cm) followed by plant spacing (10 cm) which showed (307.88) of leaf area duration, while minimum leaf area duration was observed in plant spacing (20 cm) having leaf area duration of (301.36). Data in the table 3 showed that the sowing time has significant effect on the net assimilation rate in pearl millet. The maximum net assimilation rate was observed in sowing time 2 that is (2.9672 g m^{-2} d^{-1}.) followed by sowing time 1 that showed minimum net assimilation rate (2.5701 g m^{-2} d^{-1}). Plant spacing's has no significant effect on net assimilation rate (CGR). Crop growth rate was significantly affected by different sowing times in pearl millet. In this case sowing time 1 had maximum crop growth rate (CGR) (31.198 g m^{-2} day^{-1}) followed by sowing time 2 having minimum crop growth rate (CGR) that gave value (26.127 g m^{-2} day^{-1}). Planting density was highly significant in leaf. The maximum crop growth rate (CGR) (30.529 g m^{-2} day^{-1}) was observed in plant spacing (15 cm) followed by plant spacing (10 cm) which showed (28.729 g m^{-2} day^{-1}) of crop growth rate (CGR), while minimum crop growth rate (CGR) (27.530 g m^{-2} day^{-1}) was observed in plant spacing (20 cm).

Yield Parameters

Table 3 showed that planting time did not have significant effect on the panicle length of pearl millet. Plant spacing showed significant effect on the panicle length of pearl millet. The maximum panicle length was observed in plant spacing (15 cm) that gave panicle length of (29.375 cm) and plant spacing (10 cm) and (20 cm) were at PAR on panicle length (26.125 cm) and (26.125 cm). there is contrast of my results with that of shown by (Leila *et al.*, 2008) who stated that the crop sown in the June has significant difference in panicle length and weight from late sown crop. The reduction in length of penicle in late sowing crop are affected due to changes in total interception of light duration (Craufurd *et al.* 1988). Planting time and plant spacing has no significant effect on the panicle girth of pearl millet. The interaction of planting time and plant spacing on panicle girth was also non-significant. Data in the table 3 has showed that the effect of planting time 1 and planting time 2 was significant for 1000-grain weight in the pearl millet. The maximum 1000-grain weight was observed in planting time 1 with value of 9.58 g followed by planting time 2 with 1000 grain weight of 9.30 g. Wailare, M.A. (2009) also reported same results that swing at 10^{th} of June has more seed weight as compared to late sown.

Data in the table 3 showed that the effect of different planting densities on 1000-grain weight was non-significant. Biological yield is the total biomass produced by the crop during the whole life cycle. The whole part comprised of different components such as stalk, plant height, leaf area index etc. The analysis of variance regarding biological yield increased steadily after crop establishment until maturity in all the treatments. Table 3 indicated that sowing time effected significantly on dry matter production in pearl millet. In this case sowing time 1 had significant effect on the dry matter production (21603 kg ha^{-1}) followed by sowing time 2 that gave (18429 kg ha^{-1}) at final harvest (95 DAS). Hancock and Durham, (2010) has stated same results that the total dry matter production was high in early sown pearl millet and it decreased with linear proportion for every day plantation delayed. The reason behind these results was that the early sown crop has got more degree days to complete its growth and development which results is maximum utilization of the assimilates to produce more dry matter production as compared to late sown pearl millet. Biological yield was significantly affected by different plant spacing. So, plant spacing (15 cm) showed maximum biological yield (20921 kg ha^{-1}) followed by plant spacing (10 cm) which showed (20162 kg) of biological yield, while minimum biological yield was observed in plant spacing (20 cm) having dry matter production of (18964 kg ha^{-1}) at final harvest (95 DAS). The interaction of sowing time and plant spacing on biological yield was also significant. The maximum biological yield was observed in sowing time 1 and plant spacing (15 cm) that gave (21815 kg ha^{-1}) and the minimum biological yield was observed in sowing time

2 (06-July-2015) and plant spacing (20 cm) that gave (16704 kg ha^{-1}) of biological yield at final harvest. Data showed that planting time and planting time has significant effect on the grain yield of pearl millet. So the maximum grain yield was recorded in sowing time 1 (20-June-2015) that gave (4391.7 kg ha$^{-1)}$ followed by sowing time 2 (06-July-2015) that gave (4049.9 kg ha$^{-1)}$ of grains. The reason behind these results was that the early sown crop has got more degree days to complete its growth and development which results is maximum utilization of the assimilates to produce more grain yield as compared to late sown pearl millet. The same results were revealed by (Soler *et al.,* 2007) a crop took more days to complete its cycle will definitely produce more biological and economical yield. Same results were also shown by Deshmukh *et al* (2009) that late sown pearl millet has produced less yield as compared to early sown because of proper time take by early sown to complete it vegetative and reproductive growth.

Table 2. The mean squares of yield and yield components of pearl millet to different sowing dates and planting densities.

Source of variation	df	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	1000-grain weight (g)	LAI	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)
Replication (r)	3	10.5	0.5972	8.031E-30	0.20	0.448	3615197	6028	3.57
DOS	1	10612.6**	57.0417*	1.037E-32 ^{NS}	0.45*	3.80*	6.04E+07**	700862**	17.02*
Error a	3	26.2	2.7083	0.22222	0.02	0.166	789848	5015	1.07
Plant Density (Pd)	2	45.7^{NS}	24.5000**	0.12500 ^{NS}	0.06 ^{NS}	0.287**	7786510**	282766**	0.64
DOS × Pd	2	20.2 ^{NS}	8.1667*	0.87500 ^{NS}	0.008 ^{NS}	0.01^{NS}	3741776**	37593**	1.72*
Error b	12	23.5	1.6111	0.27778	0.07	0.025	203589	2852	0.35
Total	23								

Table 3. The response of yield and yield components of pearl millet to different sowing dates and planting densities.

Treatments	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	LAI	1000-grain weight (g)	Biological yield (t ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)
Date of Sowing (DOS)								
DOS$_1$	185.32^a	28.917^a	11.5^a	6.4579^a	9.5833^a	21603^a	4391.7^a	46.450^a
DOS$_2$	143.26^b	25.833^b	11.5^a	5.6615^b	9.3083^b	18429^b	4049.9^b	45.475^b
LSD (P=0.05)	6.6511	2.1381	0.6125	0.529	0.1906	1154.7	92.003	1.3475
Planting Density (Pd)								
Pd$_1$	166.37^a	26.125^b	11.37^a	6.0382^b	9.4625^a	20162^b	4200.8^a	49.328^c
Pd$_2$	164.82^a	29.375^a	11.62^a	6.2591^a	9.5250^a	20921^a	4288^a	44.973^b
Pd$_3$	161.68^a	26.125^b	11.5^a	5.8818^b	9.3500^a	18964^c	3796.3^b	41.580^a
LSD (P=0.05)	5.2810	1.3828	0.5742	0.1726	0.3044	491.55	58.182	0.6483

Means sharing same letters did not differ significantly at P = 0.05.

Table 4. The response of yield and yield components of pearl millet to different sowing dates and planting densities.

Treatments	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	LAI	1000-grain weight (g)	Biological yield (t ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)
Interaction (ST × T)								
DOS$_1$ × Pd$_1$	189.23^b	27.500^b	11.750^a	6.4483^{ab}	9.5750^a	21769^a	4351.7^b	49.768^a
DOS$_1$ × Pd$_2$	184.87^d	30.00^a	11.750^a	6.6891^a	9.6500^a	21815^a	4532.5^a	44.942^c
DOS$_1$ × Pd$_3$	181.86^f	29.25^{ab}	11.750^a	6.2362^{bc}	9.5250^a	21225^{ab}	4290.8^c	43.246^d
DOS$_2$ × Pd$_1$	143.51^{bc}	24.750^c	11.00^a	5.6280^{de}	9.3500^a	18556^c	4049.9^c	48.887^{ab}
DOS$_2$ × Pd$_2$	144.78^e	28.750^{ab}	11.5^a	5.8290^{cd}	9.4000^a	20028^b	4043.6^b	45.004^c
DOS$_2$ × Pd$_3$	141.49^f	24.00^c	11.25^a	5.5273^e	9.1750^a	16704^d	3796.3^d	39.914^c

LSD (P=0.05)	7.4645	1.9515	0.8120	0.2441	0.4304	695.16	82.281	0.9169

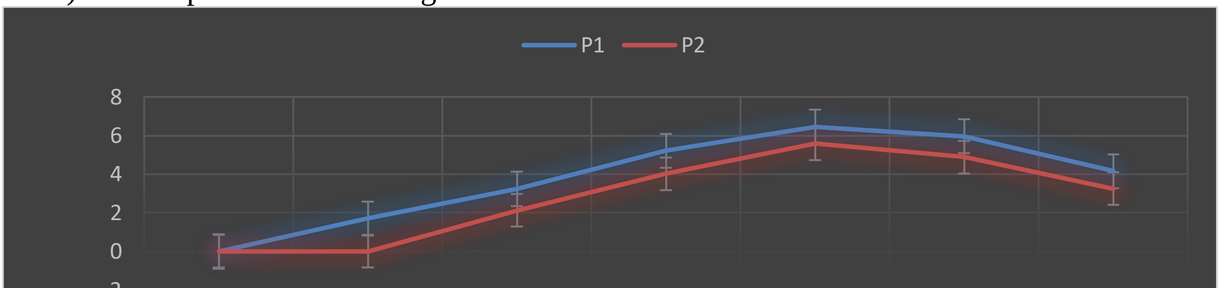
Means sharing same letters did not differ significantly at P = 0.05.

The effect of plant spacing was recorded significant in the grain yield of pearl millet. The maximum grain yield was recorded in plant spacing (15 cm) that gave (4288 kg ha^{-1}) followed by plant spacing (10 cm) that gave (4200.8 kg $ha^{-1)}$ of grains and this is also at PAR with plant spacing (10 cm). The minimum grain yield was recorded in plant spacing (20 cm) that gave (4043.6 kg ha^{-1}) of grain yield. The interaction of planting time and plant spacing on grain yield of pearl millet was showing significant effect. The maximum grain yield was observed in sowing time 1 and plant spacing (15 cm) having value (4532.5 kg ha^{-1}) and the minimum amount of grain yield was observed in sowing time 2 and plant spacing (20 cm) that gave grain yield of (3796.3 kg ha $^{-1}$). Harvest index (HI) was significantly affected by different sowing times in pearl millet. However, the maximum harvest index (HI) of (22.04 %) was observed in planting time 2 and the minimum harvest index (HI) of (20.36 %) was recorded in planting time. Harvest index (HI) was not significantly affected by different planting densities. The interaction between planting time and plant density on harvest index (HI) was significant. Data in the table 4 showed that of planting time 2 and planting density (10 cm) has significant effect on the harvest index (HI) (21.858 %) followed by planting time 2 and planting density (15 cm) having harvest index (HI) of (21.519 %). The minimum value of harvest index (HI) was observed in the planting time 1 and planting density (10 cm) having value (20.01 %). Late sowing of pearl millet causes significance loss in all the parameters (Upadhyay *et al,* 2001).

Discussion

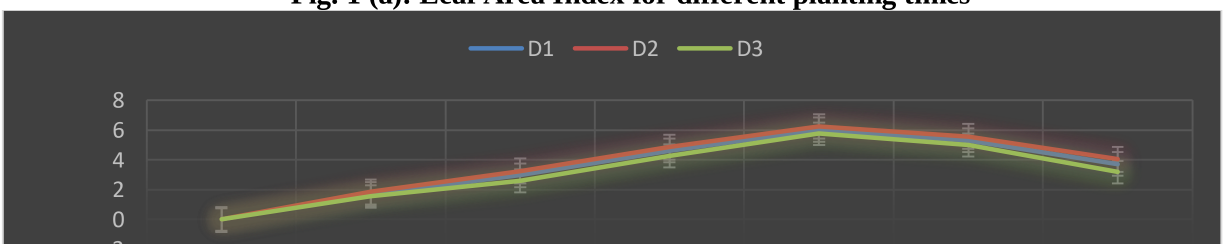
Plant height is generally measured by vegetative growth of plant. This growth of plant is not only affected by genetic variability of the cultivar but also significantly influenced by environmental factors Individual comparison of treatment means in case of sowing time revealed that early sowing performed better than the late sowing. The reason behind these results was that the early sown crop has got more degree days to complete its growth and development which results is maximum utilization of the assimilates to produce more height of plants as compared to late sown pearl millet. In early sowing 189.50 cm plant height was observed as compared to the 182.43 cm in late sowing (Majid *et al*., 1986). (Belachew and Abera, 2010) also confirmed the results by reporting that plant height was more in early sowing. Results in the table 3 were showing same trend for 1000-grain weight in early sowing treatment as reported by (Siddig *et al.*, 2013). The reason behind these results was that the early sown crop has got more degree days to complete its growth and development which results is maximum utilization of the assimilates to produce more grain weight as compared to late sown pearl millet. He also revealed that pearl millet has shown substantial increase in the 1000-grain weight in early sowing. In early sowing it has more days to complete its physiological and reproductive growth. Leaf area index was smoothly increased and reached to its maximum value after the half stage of the crop and it also declined to minimum at full maturity. Greater LAI could be attributed to significant expansion in leaf area. Data trend is same for early sowing of millet as reported by (Siddig *et al*., 2013). They revealed that pearl millet is showing substantial increase in the leaf area index in early sowing. Fig. 1 (a) shown the same trend for early sowing in case of LAI. In early sowing it has more days to complete its physiological and reproductive growth. Our results were also in accordance with (Al-Suhaibani, 2011) who reported that in pearl millet, if plant spacing is more this will lead towards more leaf area and leaf area index. We can see the same trend for LAI in

Fig.1 (a). The increase in biological yield in early sowing was due to better crop growth, which gave maximum plant height, LAI and ultimately produced more biological yield. Our results were not in accordance with (Cox and Cherney, 2001) who reported that if planting density is high than optimum then there will be a significant increase in biological yield. Our results were showing same trend as reported (Singh and Singh, 1979) who reported that sowing in end of June and optimum plant spacing and crop stand for better biological yield in millet in specific environment. Same trend can be observed in the Fig.2 (a) and (b) for biological yield in case of pearl millet. Grain yield is also known as the economic yield. (Zhuang and Yu-Bi, 2013) has revealed that leaf area index and biological yield can be affected by different planting densities. He also revealed that optimum plant population



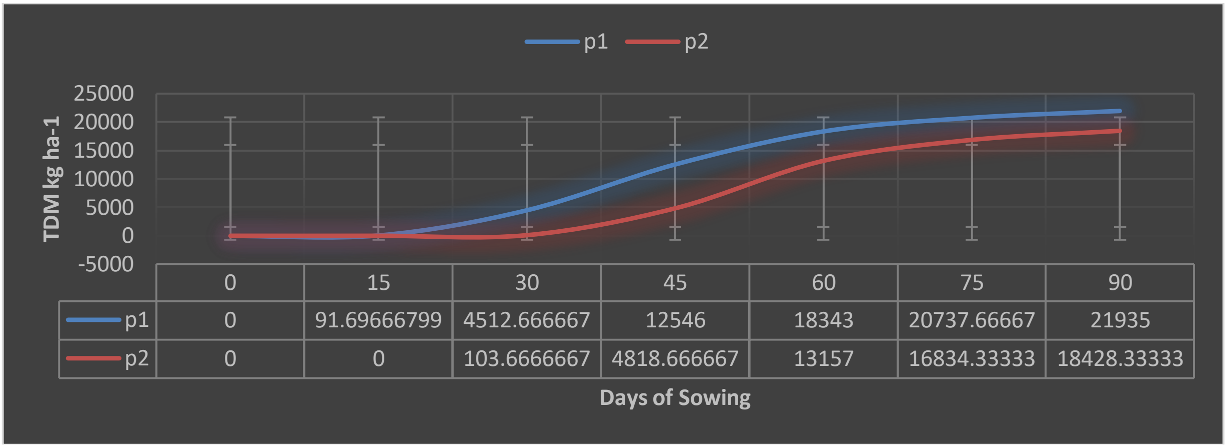
	0	15	30	45	60	75	90
P1	0	1.702877	3.236528833	5.20976319	6.458719167	5.960508333	4.152246667
P2	0	0	2.113655	4.019422642	5.581928	4.88179275	3.249595

Fig. 1 (a): Leaf Area Index for different planting times



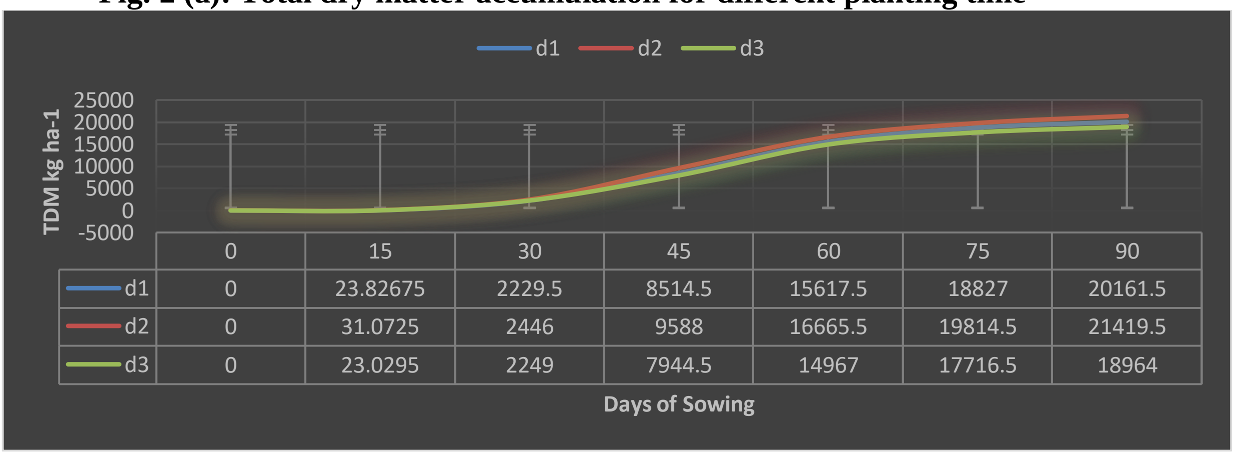
	0	15	30	45	60	75	90
D1	0	1.69664	2.97641125	4.626484375	6.035123625	5.323226625	3.72062125
D2	0	1.856003	3.25984875	4.85314125	6.25905625	5.5745575	4.04723125
D3	0	1.555988	2.58901575	4.263986838	5.766790875	5.0056675	3.18491

Fig. 1 (b): Leaf Area Index for different planting densities



	0	15	30	45	60	75	90
p1	0	91.69666799	4512.666667	12546	18343	20737.66667	21935
p2	0	0	103.6666667	4818.666667	13157	16834.33333	18428.33333

Fig. 2 (a): Total dry matter accumulation for different planting time



	0	15	30	45	60	75	90
d1	0	23.82675	2229.5	8514.5	15617.5	18827	20161.5
d2	0	31.0725	2446	9588	16665.5	19814.5	21419.5
d3	0	23.0295	2249	7944.5	14967	17716.5	18964

Fig. 2 (b): Total dry matter accumulation for different planting densities

can increase the leaf area index and if leaf area index is increased it will ultimately affect the biological yield. Research indicated that if plant density is high in case of pearl millet, this will result in high grain yield. June sowing millet gave more grain yield as compared to July. Same trend is also reported by (Wilson *et al.*, 1995) that pearl millet sown in June depicted more grain yield as compared late sown. The reason behind these results was that the early sown crop has got more degree days to complete its growth and development which results is maximum utilization of the assimilates to produce more grain yield as compared to late sown pearl millet. Cultural practices such as sowing time and cropping density affect the potential of a crop towards its yield and its stability (Safari *et al.*, 2008). Harvest index (HI) shows the physiological efficiency of plants to convert the fraction of photo assimilates to grain yield. it is reported that late sowing effects the harvest index adversly wich is according to our results shown in table 3 (Shah *et al.*, 2006).

Conclusion

20th of June is the best time for the sowing of pearl millet to better physiological, growth and yield parameters in the semi-arid environment. Also planting density of 15cm found best in all these parameters. So, in semi-arid environment pearl millet must be sown on 20th June with 15cm of plant to plant distance.

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