Original paper Open Access

Feasibility of Late Transplanted Summer Pearl Millet for Prolonged *rabi* Season With Integrated Nitrogen Management Under Indian Coastal Region

Nitin N. Gudadhe, J. D.Thanki, R. M.Pankhaniya, V. P. Usdadia

Department of Agronomy, N. M. College of Agriculture, Navsari Agricultural University, Gujarat, INDIA

* Corresponding author: E-mail: nitbioworld@gmail.com

Keywords: *Economics, Integrated Nitrogen Management, Pearl millet, Transplanting, Yield*

Abstract

Experiments were conducted in coastal South Gujarat region of India to evaluate the feasibility of late transplanted summer pearl millet under prolonged *rabi* season with integrated nitrogen management (INM) during 2014, 2015 and 2016. INM treatments were consisted of four combinations of biocompost and inorganic nitrogen fertilizers. Two planting methods were evaluated, namely drilling and transplanting. Premature heading in transplanted pearl millet was observed up to 8-10% population during all the three experimental years, the possible causes for this are slow nitrogen availability, weather conditions, the thickness of the seedlings, root pruning and seedling age at transplanting. Application of 100% Recommended Dose of Fertilizer (RDF) + 5 t biocompost had significantly increased growth, yield (3862 kg ha^{-1}), benefit-cost ratio (B:C ratio) (3.52) and quality of parameters of pearl millet followed by 75% Recommended Dose of Nitrogen (RDN) + 25% RDN through biocompost. Late transplanted summer pearl millet was little feasible to grow over timely drilled pearl millet as it had reduced pearl millet grain yield by 6.07% and also reduced the net profit by 72.46 US $ ha^{-1}. However, overall, it was feasible to grow late transplanted pearl millet and gave yield up to 3150 kg ha^{-1} in prolonged *rabi* season condition for brining summer season well in time.

Introduction

Pearl millet is a staple food of arid and semiarid regions of India. In marginal environments, pearl millet is the only cereal crop that gives reliable yield, and at the same time, it responds to high management practices. Pearl millet grains are nutritious and are a vital component for the daily human diet, and its stover acts as the primary maintenance ration for ruminant livestock in the dry season. Also, pearl millet grains use is increasing as a feed for poultry and livestock. It is sixth important cereal crop of our world. After rice and wheat, pearl millet is the most widely grown cereal crop in India (Yadav, 2011). In India area of pearl millet decreased minutely from year 1950-51 to 2014-15 by 9.02 to 7.31 million ha.Conversely, production of pearl millet was increased from year 1950-51 to 2014-15 by 2.6 to 9.18 million tonnes. This swift in production was possible due to trebling of pearl millet production from year 1950-51 to 2014-15 by 288 to 1255 kg ha^{-1}. Pearl millet is grown mainly as a rainfed crop, except in summer, where it is grown as an irrigated crop (Charyulu et al, 2016). Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana are the major pearl millet growing provinces of India and contribute 90% acreage of pearl millet in India.

One of the critical challenges of the 21st century is to feed the 9.1 billion people in 2050 through sustainable production of food grains under limited water resources and scarce land availability (Selvaraju et al, 2011). From a plant nutrition point of view, nitrogen is a most crucial component; amino acids, proteins, enzymes, carriers, nucleic acids, alkaloids, regulators, pigments and other metabolites involve N in their biosynthesis and inter-conversions (Srivastava and Singh, 1999). Up to a varying degree, the soils are universally deficient in N; hence N is the most applied nutrient from external sources (Wade, 2009). To maintain the productivity of crops, today's agricultural system heavily depend on the high application of N fertilizer (Evenson and Gollin, 2003). INM is a combination of N from chemical fertilizers and organic sources;- it includes N fixed by biofertilizers and legumes and organic N sources such as vermicompost, farm yard manure, biocompost, compost, animal refuse and crop residues. INM is gaining attention in recent years in the perspective of sustainable soil productivity. Use of INM system will not only reduce the heavy load of catering of chemical fertilizers but also use of balanced use of organic with inorganic fertilizers to supply all essential nutrients and assurance of quality apart from maintaining soil fertility (Srivatsava et al, 2015).

Transplanting in pearl millet and sorghum is a traditional practice which compensates crop growth period to complete crop life cycle (Oswald et al, 2001). The practice of transplanting can optimize crop density and crop yield. 20-25 days old seedlings of pearl millet were found best for transplanting (Khairwal et al, 1990). The harvesting time of maize can be curtailed up to 1-3 weeks and 10-15 days respectively in the USA and France, depending on seedlings age for transplanting. As the age of maize seedlings increased during transplanting, crop harvest time was reduced up to six days. However, crop growth and yield decrease with an increase in seedling age at the transplanting (Waters et al, 1990; Mapfumo et al, 2007).

South Gujarat is a coastal region situated at the coastal Arabian Sea of India which is very near to the Deccan plateau comprising of Bharuch, Navsari, Surat and Valsad districts. The soils of this region are heavy black, which are having a parent material of Basalt rock. District Valsad and Navsari are receiving high rainfall. Clay soils of this region remain wet for a long time after *kharif* rice harvest and hence rabi season prolongs up to March. Summer pearl millet planting time is 10-15 February but planted by 5-10 March due to prolonged summer season. Hence pearl millet exposed to early monsoon showers and massive loss is faced by farmers. An attempt of changing planting time of pearl millet was made through a transplanting of pearl millet with INM, so that the crop can be harvested before the onset of early monsoon showers in coastal conditions well in time.

Materials and Methods

Location and soil of experimental field plot

The experiment was carried out for three crop seasons of February-May 2014-2015-2016 at Navsari Agricultural University, Navsari, Gujarat, India (25°-57' N Latitude and 72°-54' E Longitude).The region enjoys a predominantly maritime climate; being situated 15 km East of the Arabian Sea coast. Before commencement of experiment pre-planting, composite soil samples were collected from the experimental site at 0-30 cm depth, and the composite sample was prepared and analyzed for physical and chemical characteristics (Table 1). The

Table 1 - Methods used for analysis of soil and plant samples

Soil analysis	Soil depth (0-30 cm)	Method of analysis
Soil pH (1:2.5)	7.7	Potentiometric pH meter (Jackson, 1973)
EC2.5 (dS/m at 25°C)	0.37	Schofield method (Jackson, 1973)
Organic carbon (%)	0.58	Walkley and Black's rapid titration method (Jackson, 1973)
Available nitrogen (kg ha^{-1})	218	Alkaline potassium permanganate method (Jackson, 1973)
Available P_2O_5 (kg ha^{-1})	40	Olsen's method (Jackson, 1973)
Available K_2O (kg ha^{-1})	321.14	Flame photometric method (Jackson, 1973)
Plant analysis		**Method of analysis**
Nitrogen (%)		Kjeldahl's digestion method (Jackson 1973)
Phosphorus (%)		Vanomolybdo phosphoric acid (Jackson 1973)
Potassium (%)		Flame photometric method (Jackson 1973)

soil texture of the experimental site was clayey in nature having 13.9% sand, 19.5% silt, and 65.6% clay with medium depth (60 cm). The soil was slightly alkaline in nature with pH of 7.7 and electrical conductivity of 0.37 dS m^{-1}. The initial bulk density of soil for 0–0.30 m depth was 1.31 g cc^{-1}. The initial nutrient status in soil was determined by using the standard procedures (Table 1). The soil was low in elemental nitrogen (N) (218.0 kg ha^{-1}), medium in elemental phosphorus (P) (40.0 kg ha^{-1}), high in elemental potassium (K) (321.14 kg ha^{-1}). The soil had an organic carbon of 0.58%.

Experimental procedure

The experimental treatments were consisted of two factors in factorial randomized block design. Factor A had four treatments of INM practices viz.100% RDF through chemical fertilizer (120:60:00 kg NPK ha^{-1}) + 5 t ha^{-1} biocompost, 75% Recommended Dose of Nitrogen (RDN) through chemical fertilizers + 25% RDN through biocompost, 50% RDN + 50 % RDN through biocompost and 100% RDN through biocompost. Biocompost was analysed for N content for all three years of experiment and the total quantity of biocompost was calculated for each treatment according to its N content. Factor B was consisting of two planting methods of pearlmillet, out of which one was timely drilling practice of sowing and other one was late transplanting of pearl millet seedlings. Drilling of pearl millet in general for three years was done on 10th February and transplanting done on 2nd March. Nursery for transplanted pearl millet was always planted on the same date of its drilling date, so that pearl millet seedlings should be ready for transplanting after 20 days during all the three years of the experimentation. Pearl millet variety GHB-558 was drilled and transplanted at a row-to-row spacing of 45 cm and plant-to-plant spacing of 10 cm in plots size of 5.4 m x 4.0 m. The crop was fertilized with the recommended dose 120:60:00 of N, P_2O_5 and K_2O kg ha^{-1}, respectively through urea and single super phosphate. Half dose of N and full dose of P was supplied at the time of planting and remaining N was applied through two equal splits at tillering and earhead initiation stage through band method of placement.

Agronomic practices

All agronomic practices recommended by Navsari Agricultural University were followed during the growth of the pearl millet crop. The area of each experimental plot was 21.6 m^2 (5.4 m x 4.0m). A buffer zone spacing of 2.0 m was provided between the plots. The outermost two rows at both sides of the plots and plant to plant population at both sides at each end of the two rows were considered as borders and excluded from the evaluation. During field preparation, agronomic practices were managed in such a way that soil moisture and initial nutrient status at the start of the season were almost uniform. The experimental area was hand-weeded to control the weeds.

Experimental observations

Five plants were randomly selected from each net plot area at harvest and the following observations were recorded. Plant height (cm) was recorded from the base to the tip of the main shoot at harvest stage. Leaf area (cm^2) was recorded through automatic leaf area meter. For dry matter accumulation (g $plant^{-1}$) five randomly selected plants were pulled out from each net plot. The plants were washed out with water to remove soil adhered to roots. Plants were allowed to sun dry first and finally, oven-dried at 65°C for 24 hours up to dry and constant weight and recorded accordingly. An emerging number of effective tillers that could bear ear head were monitored and recorded. Length of earhead (cm) and girth of earhead was measured from the selected earhead from each net plot.Grain yield per plant (g) was recorded after harvest from each netplot. Test weight (g) of 1000 grains from the bulk sample for each treatment was worked out.Grain and straw yield of each net plot was measured and converted into kg per hectare. Nitrogen content of seed was determined by micro Kjheldahl's method (Jackson, 1973). Protein content of seed was determined by multiplying nitrogen percentage with 6.25. Protein yield (kg ha^{-1}) was calculated by multiplying protein content in seed and seed yield.

Nutrient composition and soil evaluation

The soil samples were collected at harvest for nutrient availability as suggested by Page et al. (1982) and analyzed treatment wise. The uptake of major nutrients was evaluated by drying plant samples in diffused sunlight then in an oven at 60°C and finely powdered to form a composite sample. The samples were further digested (diacid extract) with 1:1 mixture of the concentrated sulfuric acid (H_2SO_4) and 30% hydrogen peroxide acid (H_2O_2) in Kjeldahl digestion unit at required temperature (Parkinson and Allen, 1975). The uptake was calculated by multiplying dry matter accumulation to N and P concentration in different parts of pearl plant i.e. straw and seed (Jackson, 1973).

Economics of pearl millet

Economics of pearl millet was calculated based on the prevailing prices during the evaluated crop seasons. The gross and net returns were calculated based on the grain and straw yield. Benefit-to-cost ratio (B:C) was calculated by dividing the gross returns from the total cost of cultivation. The cost of cultivation of pearl millet (US \$ ha^{-1}) and inputs cost for the cultivation of pearl millet (US \$ ha^{-1}) was calculated by summation of all inputs. The B:C ratio was calculated by using following expression: B:C = Gross returns (US \$ ha^{-1}) / Cost of cultivation (US \$ ha^{-1}).

Statistical analysis

The experiment was conducted in a two-factor randomized block design, wherein INM was allocated in four treatments viz. 100% RDF through chemical fertilizer (120:60:00 kg NPK ha^{-1}) + 5 t ha^{-1} biocompost, 75% Recommended Dose of Nitrogen (RDN) through chemical fertilizers + 25% RDN through biocompost, 50% RDN through chemical fertilizers + 50 % RDN through biocompost and 100% RDN through biocompost with two pearl millet planting method namely drilling and transplanting. A statistical analysis of results obtained from the various plots and treatments (eight treatment combinations) with the standard analysis of variance (ANOVA). The treatment effect was worked out on the basis of the least significant difference (LSD) at 5% probability level (Gomez and Gomez, 1983).

Results and discussion

Climatic conditions

The climate of the experimental site was typically tropical, characterized by humid, diurnal and warm monsoon with heavy rainfall (1600 mm). Monsoon starts by the second fortnight of June and ceases by the end of September. Usually, the summer season commences during the middle of February. Monthly averages of meteorological variables, including temperature, relative humidity, and evaporation, were measured at the automatic weather station (Figures 1, 2 and 3). During the growing period of three years the minimum and maximum temperature, minimum and maximum relative humidity and evaporation varied from 12.8 to 38.0 °C, 21.1 to 91.4% and 3.9 to 7.4 mm day^{-1}, respectively. 10 mm rainfall was recorded in March during the second season of the experiment, however, no rainfall recorded during the first and third season of the experiment. During first two years maximum humidity fell below 80% just before transplanting, and it was stable (80-90%) thereafter, however during third-year maximum humidity did not fall below 80% before transplanting of pearl millet but it fell up to 70-75%, respectively at reproduction and just before maturity time. Maximum temperature, during 2016 did not fall below 30 °C, however, it does during 2014 and 2015, but maximum temperature always ranged between 30-40 °C during all three years.

Premature heading

Pearl millet was planted through drilling and transplanting methods. Pearl millet drilling was done on 10th February during all the crop seasons. Parallelly, pearl millet nursery was prepared on the same day (10th February) for transplanting at the age of 20 days and the transplanting was done accordingly (2nd March) for all three years. The seedlings established 12-15 days after transplanting. The premature heading of the transplanted pearl millet was observed just a week after its establishment without its complete vegetative growth (Fig. 4). This premature heading was common in all the nitrogen management treatments in which pearl millet seedlings were transplanted. The emerged heads were very small in length (6-8 cm). Premature heading was up to 8-10% of the total population of transplanted pearl millet. The premature heads resulted without flowering and no grain setting was observed. On the other hand, pearl millet drilled on 10th February showed negligible premature heading and its vegetative growth, flowering and seeding resulted as a normal crop during all the three crop seasons. Premature heading in nitrogen management treatments was increased with increase in biocompost content ($N_1 < N_2 < N_3 < N_4$). The possible reasons for the premature heading of pearl millet may be due to slow availability of N, weather conditions, the thickness of the seedlings, root pruning and seedling age at transplanting.

The treatment, 100 % RDF + 5 t Biocompost (N_1) received a full dose of fertilizers in addition to organic manure biocompost and this treatment recorded negligible premature heading in transplanted pearl millet. However, as the dose of biocompost increased from N_2 to N_4 premature heading percentage was also increased in transplanted pearl millet. On the other side, in case of drilled pearl millet, no similar findings were recorded. It means that a full dose of fertilizers helped for luxuriant growth of drilled pearl millet which did not require extra time to set. On the contrary, transplanted pearl millet took at least two weeks to get set. Slow availability of nitrogen through biocompost might have hampered early growth of transplanted pearl millet seedlings; this nutrient stress might have converted to early senescence in transplanted pearl millet i.e. premature heading. In general, pearl millet is a crop of the arid and semi-arid areas where annual rainfall is < 800 mm. It can be successfully grown through drilling and transplanting. Chauhan et al. (2015) studied the feasibility of transplanted pearl millet at Navsari over drilling, and they observed that drilled and transplanted pearl millet showed equal yield potential. On the contrary, transplanted pearl millet was superior over drilled method studied at Anand, India under non-coastal climate (Patil et al, 2014). However, Navsari is a coastal high rainfall zone, but still drilled pearl millet highlighted good yield up to 40 q ha^{-1}. The possible cause of premature heading of 8-10% population of pearl millet may be due to the high relative humidity in the air and also very narrow diurnal variation in the temperature at Navsari station, which may have caused some physiological changes in the crop attending early maturity. The thickness of pearl millet seedling stem at the time of transplanting may also matter for premature heading. In general, those seedlings which were prematurely headed showed thin stem, whereas thick stem seedlings were grown luxuriantly and were not headed prematurely.

Root pruning of pearl millet is a common practice of dry land area where farmers plough the soil between two rows of the standing crop to initiate early flowering of the crop in anticipation of moisture shortage to cut short the total duration of the crop. In this experiment, seedlings were uprooted and transplanted at the age of 20 days from nursery to field. In seedling uprooting process also, the roots get broken. Seedlings root breaking while uprooting is also a type of root pruning. Hence, premature heading of pearl millet may be due to greater uprooting shock to some seedlings, which are exposed to early reproduction of crop. Transplanted plants perish in early development stages due to mechanical injuries to their roots and their root-soil contact also gets disturbed. It means that transplanted pearl millet seedlings requires sufficient time to regenerate new roots and to be adapted in the new environment. Also, late sown pearl millet get flowered and matured early due to early cessation of rainfall (Murungu et al, 2006). Fisher and Turner (1978), concluded that wheat and barley had shown early maturity due to moisture stress. This may be the reason why, whenever plants expose to different types of stress, they shrinks their life cycle and fruit and flower early.

Seedling age at the time of transplanting does matters for its establishment, growth, flowering, fertilization, seeding and ultimately its yield. Generally it is a thumb rule in agronomy, that the age of the seedlings of the cereal crop for transplanting should be ¼ of the total life span of the plant. Summer pearl millet is a crop of 90-95 days life period. In this experiment, pearl millet seedlings were transplanted at the age of 20 days which is nearly equal to ¼ life span of 90 days crop. Rathore and Gautam (2003) in non-coastal region at New Delhi, India compared the drilling and transplanting methods of planting, they have used 20 days old seedling during *kharif* season and they had found that drilled pearl millet had given slightly higher grain yield over transplanted pearl millet which was statistically significant. Singh et al. (2017) in non-coastal region at Gwalior, India have also confirmed that 20 days aged seedling gave more grain yield over 15 and 25 days old seedlings of pearl millet. Feasibility of *rabi*-transplanted pearl millet was studied by Chudasama et al. (2017), they had transplanted pearl millet seedlings on six different weeks and they have recommended three weeks old seedlings for achieving a highest profitable yield of pearl millet. On the contrary, Murungu et al. (2006) at Save Valley, Zimbabwe which is a non-coastal region have transplanted at the age of 20, 30 and 40 days, but they showed that the seedlings which were transplanted at the age of 30 days reached highest yield. Also, direct-sown pearl millet had better crop establishment over transplanted because of irrigation supplied before transplanting. When transplanting delayed the plant stand was also decreased, 20 days old seedlings showed better stand over 30 and 40 days seedlings. Pearl millet had three growth phases: Emergence to floral initiation (GS1), floral initiation to anthesis (GS2) and anthesis to physiological maturity (GS3) (Eastin, 1972). In the study of Murungu et al. (2006), the number of seeds per plant for the transplants increased with increase in ages of transplants.The stress due to transplanting was found in younger seedlings due to interruption of the GS2 phase. Due to delayed sowing, the seed weight was reduced due to early hastening of maturity. Early maturity reduced leaf area duration and GS3 phase, curtailed assimilate supply to grain before it reach to its yield potential. Late sowing of pearl millet reduced yield as the number of grains per heads reduced as sowing was late for transplants. Though transplanting reduced dry weight but it did not significantly affect grain yield. Hence without affecting yield potential of pearl millet, transplanting can be delayed up to 30 days. However, in this experiment, pearl millet planting was done through transplanting method, which was delayed by 20 days than normal planting time. However, drilled pearl millet reached higher pearl millet grain yield over transplanting.

Growth and yield contributing characters

All growth contributing characters influenced significantly with the application of different treatments. Application of 100 % RDF + 5 t biocompost registered significantly highest growth and yield contributing characters namely plant height (156.22 cm), leaf area (2297 cm^2), dry matter (123.83 g), effective tillers (5.38), ear head length (23.48 cm), ear head girth (10.13), grain yield per plant (31.71 g) and test weight (8.68 g) and which were found at par with effective tillers (4.86) and grain yield per plant (28.63 g) by application of 75% RDN + 25% RDN through biocompost (Table 2). Application of 100% RDN resulted in significantly higher growth and yield contributing characters, but it was found at par with an application of 70% RDN + Azospirillum (Chauhan et al, 2015). Wellness of all plant parts depends on the availability of nitrogen to crops and it is responsible for plant growth, transportation, absorption and excretion. These results are in agreement with Rathore and Gautam (2003). Observation of lowest growth and yield contributing were reported by the treatment which has received 100% RDN through biocompost. In an experiment including the effect of organic and inorganic N on crops, Okamoto, et al (2003) revealed that during the early growth stage of rice and sorghum, they are efficient to utilize organic N in soil and had higher biomass and N uptake through organic nitrogen application. On the other hand, pearl millet and maize are not efficient enough to utilize organic nitrogen from the soil like rice. Hence the application of 100% RDN through biocompost showed the lowest growth and yield contributing characters over INM treatments.

Among planting method treatments, drilled pearl millet highlighted significantly higher plant height (139.46 cm), leaf area (2061 cm^2), dry matter (106.88 g), effective tillers (4.67), earhead length (21.11 cm), ear head girth (9.40 cm), grain yield per plant (27.49 g) and test weight (7.91 g) over transplanted pearlmillet. Chudasama et al. (2017) studied six different planting dates of pearl millet, and they had found that third week of transplanting had given highest growth and yield contributing characters followed by the second week, but at fourth, fifth and sixth-week growth and yield con-

Table 2 - Effect of INM (Integrated Nitrogen Management) and planting methods on growth of pearl millet (Pooled mean of 3 years)

Treatments	Plant height (cm)	Leaf area (cm^2)	Dry matter (g)	Effective tillers	Earhead length (cm)	Earhead girth (cm)	Grain yield/ plant (g)	Test weight (g)
Nitrogen (N)								
100 % RDF + 5 t Biocompost	156.22	2297	123.83	5.38	23.48	10.13	31.71	8.68
75 % RDN + 25 % RDN through Biocompost	141.05	2074	111.81	4.86	21.20	9.28	28.63	7.84
50 % RDN + 50 % RDN through Biocompost	133.14	1896	97.38	4.26	19.29	8.82	25.07	7.33
100 % RDN through Biocompost	109.95	1731	82.28	3.59	17.47	8.25	21.14	6.86
S.Em. ±	3.67	51.77	5.23	0.21	0.52	0.24	1.19	0.16
CD at 5%	10.36	146.19	18.11	0.69	1.48	0.67	4.12	0.46
Planting (T)								
Drilling (10 February)	139.46	2061	106.88	4.67	21.11	9.40	27.49	7.91
Transplanting (2 March)	130.72	1938	100.62	4.38	19.61	8.84	25.79	7.44
S.Em. ±	2.70	37.32	1.83	0.09	0.37	0.17	0.55	0.11
CD at 5%	7.64	105.48	5.18	0.25	1.04	0.48	1.55	0.33
Interaction (N x T)								
S.Em. ±	5.62	121.98	6.19	0.28	0.73	0.59	1.64	0.47
CD at 5%	15.86	NS	NS	NS	2.06	NS	NS	NS

tributing parameters declined. In this experiment also pearl millet seedlings were transplanted at third week and gave good yield of pearl millet. On the other hand, Patil et al. (2014) reported contrasting results and revealed that transplanted pearl millet showed significantly higher growth and yield contributing characters over drilled pearl millet. Murungu et al. (2006) observed that early sown pearl millet reached higher plant height than late sown one. Late sown pearl millet partitioned dry matter differently than early sown. The interaction between nitrogen and planting methods was found significant with regard to plant height and ear head length.

Yield

Grain and straw yield of pearl millet were significantly influenced by the treatment of the different combination of organic and inorganic sources of nitrogen. Application of 100 % RDF + 5 t biocompost showed significantly higher grain yield (3670, 4020, 3895 and 3862 kg ha^{-1}, respectively) and straw yield (6491, 7231, 6799 and 6841 kg ha^{-1}, respectively) of pearl millet during all the three years and in pooled mean too (Table 3). The comparative increase in pooled pearl millet grain and straw yield due to 100 % RDF + 5 t biocompost was 49.74 and 52.09 %, respectively, over the treatment which has received lowest grain and straw yield (N4). Srivastava et al. (2015) studied different INM treatments along with only treatment of organics, they had found that 100% RDF (NPK) + FYM at 10 t ha^{-1} was significantly superior over 100 % organic treatments FYM at 10 t ha^{-1} and vermicompost at 2.5 t ha^{-1} . The pearl millet grain yield was 7.5 and 10% higher by application of FYM at 10 t ha^{-1}over 100 % RDF (NPK) + FYM at 10 t ha^{-1} which, also, confirms the findings of this experiment. Singh et al. (2003) reported the significance of integrated nutrient management, they have studied one integrated nitrogen treatment 80 kg N + 5 t FYM and one fully inorganic treatment 120 kg N ha^{-1} and they showed that application of 120 kg N ha^{-1} was at par with 80 kg N + 5 t FYM. Hence 40 kg N can be saved by a combination of organics with inorganic. Moharana et al. (2017) also studied 100 % NPK and 100 % NPK + FYM, and they have found that 100 % NPK + FYM given significantly higher grain yield over the only application of 100% NPK. In this experiment grain and straw yield of pearl millet were found at par with the application of 75% RDN + 25% RDN through biocompost during all three years and in pooled basis in case of grain yield (3317, 3637, 3507 and 3487 kg ha^{-1}, respectively) and first two years for straw yield (5595 and 6573 kg ha^{-1}, respectively). These results are in agreement with Gudadhe et al. (2015) for the integration of vermicompost with chemical fertilizers in cotton crop. Rathore and Gautam (2003) found the same results with use of 40 kg N + 30 kg P_2O_5 ha^{-1} + biofertilizers over the only use of 60 kg N and 45 kg P_2O_5. Harvest index varied between 0.32 to 0.40; however, no spe-

Table 3 - Effect of INM (Integrated Nitrogen Management) and planting methods on yield of pearl millet (Pooled mean of 3 years)

Treatments	Grain Yield (kg ha^{-1})				Straw yield (kg ha^{-1})				Harvest index			
	2014	2015	2016	Pooled	2014	2015	2016	Pooled	2014	2015	2016	Pooled
Nitrogen (N)												
100 % RDF + 5 t Biocompost	3670	4020	3895	3862	6491	7231	6799	6841	0.34	0.38	0.37	0.36
75 % RDN + 25 % RDN through Biocompost	3317	3637	3507	3487	5895	6543	5781	6073	0.34	0.38	0.38	0.37
50 % RDN + 50 % RDN through Biocompost	3229	3419	2475	3041	5764	6112	3711	5196	0.35	0.38	0.40	0.37
100 % RDN through Biocompost	2503	2929	2305	2579	4426	5275	3793	4498	0.32	0.40	0.38	0.37
S.Em. ±	133	146	151	144	261	301	321	177	-	-	-	-
CD at 5%	392	430	445	501	768	887	946	501	-	-	-	-
Planting (T)												
Drilling (10 February)	3339	3673	3019	3344	5923	6751	4625	5767	0.33	0.39	0.40	0.37
Transplanting (2 March)	3020	3329	3070	3141	5365	5829	5417	5537	0.34	0.38	0.37	036
S.Em. ±	94	103	107	60	184	213	227	124	-	-	-	-
CD at 5%	277	304	NS	169	543	627	NS	351	-	-	-	-
Interaction (N x T)												
S.Em. ±	188	206	214	183	369	426	455	245	-	-	-	-
CD at 5%	555	608	NS	NS	1086	1255	NS	692	-	-	-	-

cific trend of harvest index was found during all three years of experimentation. Lowest grain (2579 kg ha^{-1}) and straw (4498 kg ha^{-1}) yield of pearl millet was observed by application of 100 % RDN through biocompost.

Among the two planting methods studied, timely drilled pearl millet at 10th February showed highest grain (3339, 3673 and 3344 kg ha^{-1}, respectively) and straw (5923, 6751 and 5767 kg ha^{-1}, respectively) yield of pearl millet over late transplanted pearl millet during the first and second year of experimentation and in pool mean also. However, during the third year, highest pearl millet grain (3070 kg ha^{-1}) and straw (5417 kg ha^{-1}) yield were found by transplanting of pearl millet, but not statistically significant. During third-year maximum relative humidity dropped down below 70% at maturity time and maximum temperature was always exactly between 30-40 °C. However during earlier two years of the experiment the maximum humidity was between 80-90 % and maximum temperature fall below 25°C during the early grand growth period of pearl millet. Hence during third-year humidity and temperature may be little favorable for transplanted pearl millet, which lead to increase in grain yield during the third year of experimentation. Both drilled and transplanted method of the planting of pearl millet were suitable for coastal Navsari conditions as both had at par results of drilled and transplanted pearl millet (Chauhan et al, 2015). Patil et al. (2014), on the contrary, reported different results and found that transplanted pearl millet showed higher pearl millet grain yield over drilled one, which is corroborating with the third-year results of this experiment. Reduced grain yield of pearl millet was observed in transplanted pearl millet over drilled method of planting during 2014, 2015 and in pooled average also by 9.55, 9.37 and 6.07 %, respectively. This reduction of grain yield during the first two years by the transplanting method may be due to premature heading of pearl millet. The premature heading may have reduced the pearl millet grain yield up to 10%. Many causes of premature heading of transplanted pearl millet may be cited, there can be unfavourable weather conditions near coastal region, as coastal conditions have high humidity throughout the year; stem thickness of the transplanted seedlings matters for comparatively higher grain yield of pearl millet. In this experiment thick seedlings transplanted pearl millet not show premature heading over thin and weak seedlings; root pruning kick starts the process of reproduction in pearl millet, the uprooting process for transplanting of pearl millet had same physiological action which may be a cause of early heading. Seedling age is responsible for growth and yield of transplanting, generally 20-21 days were found to be best by number of researchers, but few workers like Murungu et al. (2006) in Zimbabwe reported that 30 days seedling caused higher pearl millet yield over 20 and 40 days old seedling, which extended the scope to test the seedling age transplanting up to 30 days. Few other researchers, like Chudasama et al. (2017), have tested the transplanting age of pearl millet seedling from one to six weeks and they had recommended that three week age seedlings is the best age for transplanting of pearl millet. In this experiment also 20 days old seedlings were applied. Interaction between nitrogen and planting methods was found significant in case of grain and straw yield during the first two years and straw yield of pearl millet on pooled mean basis. However, the interaction for grain and straw yield of pearl millet was not found significant during the third year and in pool mean.

Economics

Economics of the INM and planting methods was found remunerative from farmers point of view. Cost of cultivation of the experiment was calculated as per the input prices of the third year. Application of 100 % RDN through biocompost has received highest cost of cultivation due to its only application through biocompost (364.55US \$ ha^{-1}), followed by 100 % RDF + 5 t biocompost (348.88 US \$ ha^{-1}) (Table 4). In case of INM treatments, application of 100 % RDF + 5 t biocompost showed the highest net monetary returns and benefit-cost ratio (879.61 US \$ ha^{-1} and 3.52, respectively) followed by 75% RDN + 25% RDN through biocompost (779.94 US \$ ha^{-1} and 3.41, respectively).This is because of the highest grain yield was secured by these treatments (3863 and 3488 kg ha^{-1}, respectively). The lowest net monetary return (452.79 US \$ ha^{-1}) and benefit-cost ratio (2.25) was observed in 100 % RDN through biocompost as its cost of cultivation was highest (364.55US \$ ha^{-1}) however grain yield (2579 kg ha^{-1}) was lowest among all four INM treatments observed. Chander et al. (2013) in a farm trial at dryland region of Tonk and Sawai Madhopur state of Rajasthan, India, where rainfall is 288 and 330 mm, advised for application of balanced nutrition with an improved cultivar of pearl millet for more economic returns and rainwater use efficiency over farmers practice. In this experiment both treatments, 100 % RDF + 5 t biocompost and 75% RDN + 25% RDN through biocompost, resulted also an integrated nitrogen approach and gave the highest net monetary returns and benefit-cost ratio. These results are in agreement with Gudadhe et al. (2016) in cotton crop. Application of integrated nitrogen treatments 50% RDN through FYM + 50 % through urea and 25 % RDN through FYM + 75 % through urea had given highest net returns (166.70 and 155.21 US \$ ha^{-1}, respectively) and benefit-cost ratio (1.95 and 1.92, respectively) over other treatments (Singh et al, 2013).

In case of planting methods, cost of cultivation of transplanted pearl millet seedling (350.94 Rs ha^{-1}) was higher over drilled one (337.21 US \$ ha^{-1}), as transplanting requires higher labour for nursery preparation, uprooting and transplanting. Among the two methods tested for planting, drilled pearl millet showed highest net monetary returns (719.55US \$ ha^{-1}) and benefit cost ratio (3.15) over transplanted (647.09 US \$ ha^{-1} and 2.86). Feasibility of late transplanted pearl millet during summer season under the coastal situation of Navsari was the premiere objective of this experiment. Transplanted pearl millet had given a three years average yield of 3141 kg ha^{-1} which was short over drilled by 203 kg ha^{-1}. Chauhan et al. (2016) compared two methods of pearl millet planting, and they revealed that drilling was superior over transplanted pearl millet in terms of net monetary returns (491.07 > 433.27 US \$ ha^{-1}) and benefit cost ratio (2.96 > 2.70). On the contrary, transplanted pearl millet showed higher net monetary (480.22 US \$ ha^{-1}) returns and benefit-cost ratio

Table 4 - Effect of INM (Integrated Nitrogen Management) and planting methods on economics of pearl millet (US \$)

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Cost of cultivation (US \$)	Gross monetary returns (US \$)	Net monetary returns (US \$)	Benefit Cost Ratio
Nitrogen (N)						
100 % RDF + 5 t Biocompost	3863	6839	348.88	1228.49	879.61	3.52
75 % RDN + 25 % RDN through Biocompost	3488	6073	324.81	1104.75	779.94	3.41
50 % RDN + 50 % RDN through Biocompost	3042	5197	338.06	959.00	620.96	2.85
100% RDN through Biocompost	2579	4499	364.55	817.34	452.79	2.25
Planting (T)						
Drilling (10 February)	3344	5767	337.21	1056.76	719.55	3.15
Transplanting (2 March)	3141	5537	350.94	998.03	647.09	2.86

Table 5 - Effect of INM (Integrated Nitrogen Management) and planting methods on nutrient uptake, protein and soil nutrients of pearl millet (Pooled mean of 3 years)

Treatment	Seed nutrient content (%)		Stover nutrient content (%)		Total nutrient uptake (kg/ha)		Protein content (%)	Protein yield (kg/ha)	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)
	N	P	N	P	N	P				
Nitrogen (N)										
100 % RDF + 5 t Biocompost	1.720	0.296	0.708	0.143	114.91	21.30	10.74	415.28	241.28	44.85
75% RDN + 25% RDN through Biocompost	1.690	0.273	0.668	0.134	100.69	17.85	10.54	372.19	200.45	36.82
50% RDN + 50 % RDN through Biocompost	1.650	0.262	0.640	0.128	87.74	15.44	10.30	325.14	211.49	44.82
100% RDN through Biocompost	1.598	0.255	0.613	0.122	69.05	12.34	9.97	256.93	227.34	37.58
SE m+	0.031	0.006	0.015	0.003	3.98	0.79	0.24	14.58	3.35	0.30
C.D. at 5 %	0.089	0.017	0.042	0.009	11.24	2.25	NS	41.20	9.47	0.85
Planting (T)										
Drilling (10 February)	1.735	0.280	0.680	0.136	99.90	17.74	10.83	368.46	214.41	40.65
Transplanting (2 March)	1.595	0.263	0.640	0.127	86.29	15.72	9.95	316.30	225.88	41.38
SE m+	0.023	0.005	0.011	0.002	2.81	1.04	0.17	10.11	2.41	0.38
CD at 5 %	0.064	0.013	0.030	0.006	7.95	NS	0.49	8.57	6.81	NS
Interaction (N x T)										
SE m+	0.044	0.017	0.040	0.008	5.66	1.76	0.34	20.29	4.82	0.66
CD at 5 %	0.125	NS	NS	NS	15.97	NS	0.96	57.32	13.63	NS

(2.62) over drilled (432.71 US $ ha^{-1} and 2.66, respectively) (Patil et al, 2014). Hence it has solved the purpose of the experiment that the grain yield reached up to 31.5 q ha^{-1}, however from economic point of view the drilled pearl millets net monetary return was higher by 72.46 US $ ha^{-1} over transplanted one. This difference of net monetary return favours towards drilled summer pearl millet, but under prolonging *rabi* season, it may be feasible to go for transplanted one.

Nutrient content and uptake

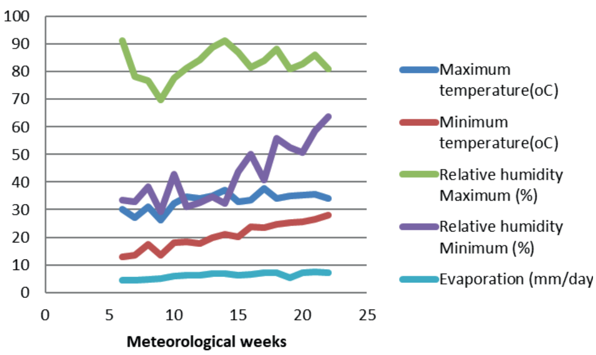

Fig. 1 - Weekly weather conditions during summer 2014

The ANOVA indicated that the INM treatments were significantly different by influencing the N and P content in pearl millet seed and straw and its respective uptake of nutrients during 2014, 2015 and 2016 (Table 5). N content in seed, straw and its total uptake ranged between 1.598-1.720 %, 0.613-0.708 % and 69.05-114.91 kg ha^{-1}, respectively. P content in pearl millet seed, straw and its total uptake ranged between 0.255-0.296 %, 0.122-0.143 % and 12.34-21.30 kg ha^{-1}. N and P content in pearl millet seed (1.720 and 0.296 %, respectively), straw (0.708 and 0.143 %, respectively) and total uptake (114.91 and 21.30 kg ha^{-1}, respectively) significantly higher was recorded by application of 100 % RDF + 5 t biocompost. It was also found at par with N content in seed (1.690 %) and straw (0.668 %) and P content in straw (0.134%) by application of 75 % RDN + 25% RDN through biocompost. The increase in N and P uptake through 100 % RDF + 5 t biocompost resulted higher by 14.12 and 19.32 %, respectively over-application of 75 RDN + 25 % RDN through biocompost. The lowest N and P content in seed (1.598 and 0.255 %, respectively) and straw (0.613 and 0.122 %, respectively) and its uptake (69.05 and 12.34 kg ha^{-1}, respectively) was observed by 100% RDN application through biocompost. The findings based on this study are in convergence with those reported by Singh et al. (2013) who referred about experiment on INM and

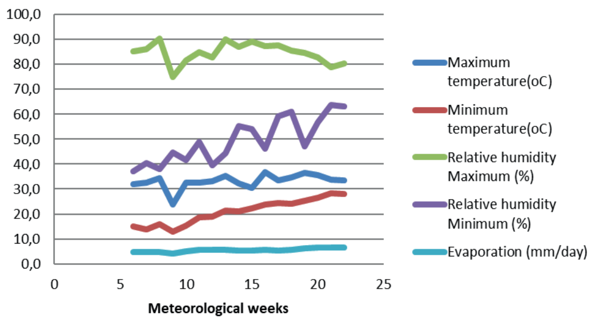

Fig. 2 - Weekly weather conditions during summer 2015

showed highest N (66.73 kg ha^{-1}) and P (14.48 kg ha^{-1}) uptake through 50% RDN through FYM + 50 % through urea, and the same INM treatment showed the highest peral millet yield under dryland region of Rajasthan. Okamoto et al. (2003) studied the effect of the organic and inorganic form of nitrogen on rice, sorghum, pearl millet and maize; they revealed that rice and sorghum xylem sap had higher proportion of organic nitrogen and both crops were more efficient to use soil organic N than maize. However, pearl millet showed the same result as rice and sorghum but the use of absorbed organic N was inefficient because of sufficient N content in pearl millet plant. Hence sorghum was more efficient to utilize organic N from the soil than pearl millet. Hence, this could explain why the treatment receiving 100% N through biocompost showed its poor results over the integrated nitrogen approach.

Significantly superior N and P content in seed (1.735 and 0.280 %, respectively) and straw (0.680 and 0.136 %, respectively) and its uptake (99.90 and 17.74 kg ha^{-1}, respectively) was observed due to drilled pearl millet over late transplanted one. The decrease in uptake of N and P in transplanted pearl millet was by 13.62 and 11.38 %, respectively, over timely drilled pearl millet. The findings based on our study are in convergence with those reported by Singh et al. (2017) for pearl millet, indicating higher N and P uptake by seed and stover when seedlings were transplanted at the age of 20 days in comparison to 15 and 25 days old seedling.

Protein content and yield

Peral millet protein content and yield under different INM treatments are shown in Table 5. Protein content was not influenced significantly by various INM treatments, however, highest protein content was observed by application of 100 % RDF + 5 t biocompost (10.74 %) and followed by application of 75 % RDN + 25 % RDN through biocompost (10.54 %). Application of 100 % RDN through biocompost showed lowest protein content in maize grain yield. This indicates that whenever a combination of organic and inorganic sources of fertilizers used, the protein content increased; however, when only the organic source of fertilizer was used, the protein content is not influenced. Nitrogen is beneficial in plants for synthesis of all amino acids and responsible for building plant protein and their various structures. Nitrogen is also important for the growth and development of important tissues. The findings based on our study are in agreement with those reported by Singh et al. (2013) under semi-arid loamy sand soil in Jobner region of Northwestern India. They have applied a combination of 50 % RDN through FYM + 50 % through urea recording the highest protein content over only organic and only inorganic sources of fertilizer. Protein yield was influenced significantly by the application of various combinations of nitrogen treatments. In this experiment also significantly superior protein yield was observed by application of 100 % RDF + 5 t biocompost (415.28 kg ha^{-1}) and which was followed by application of 75 % RDN + 25 % RDN through biocompost (372.19 kg ha^{-1}). The highest protein yield by application of 100 % RDF + 5 t biocompost was connected to the highest pearl millet yield recorded by this treatment.

Protein content and its yield were influenced significantly by planting methods. Significantly highest protein content and yield was observed by regular drilling method (10.83 % and 368.46 kg ha^{-1}) over lately transplanted pearl millet (9.95 % and 316.30 kg ha^{-1}). Hence it was observed that regularly planted crops show good growth, yield and quality characters over lately planted crops. Deshmukh et al. (2013) used three drilling methods at Navsari at 25th January, 5th February and 15th February. Drilling of pearl millet on 5th February highlighted the highest N content in pearl millet, suggesting that timely planting is very important to reach the highest protein content in pearl millet.

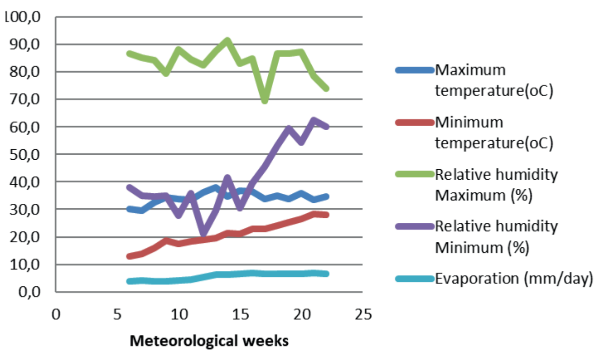

Fig. 3 - Weekly weather conditions during summer 2016

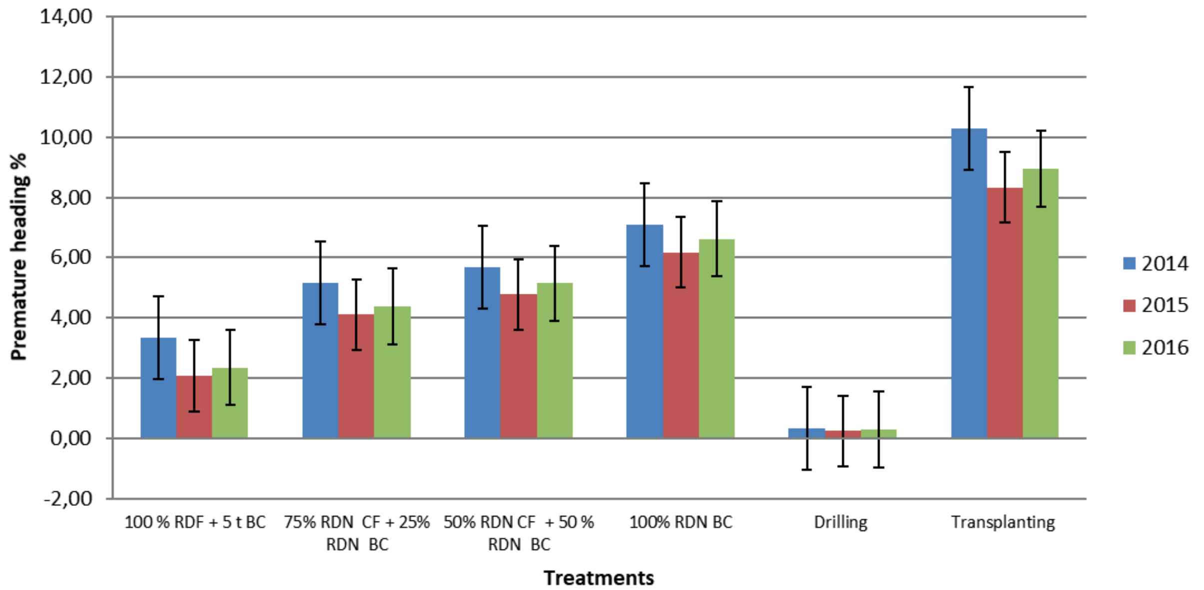

Fig. 4 - Premature heading influenced by different treatments: nitrogen and planting method. RDF: Recommended Dose of Fertilizer; RDN: Recommended Dose of Nitrogen

Elemental nutrients in soil

The residual soil fertility of nitrogen and phosphorus under different RDN treatments in pearl millet are given in Table 5. The ANOVA indicated that the treatments were significantly different by influencing the residual soil fertility of available elemental N and P in pooled mean of three experimental years. Available elemental N and P in soil ranged between 227.34-241.28 and 36.82-44.85 kg ha^{-1}, respectively, for integrated nitrogen management. Significantly highest residual elemental N and P in soil was noticed in the treatment receiving 100 % RDF + 5 t biocompost (241.28 and 44.85 kg ha^{-1}, respectively), which was followed by 100 % RDN through biocompost for residual N (227.34 kg ha^{-1}) and 50 % RDN + 50 % RDN through biocompost for residual P (44.82 kg ha^{-1}). Lowest elemental N and P resulted by application of 75 % RDN + 25 % RDN through biocompost (200.45 and 36.82 kg ha^{-1}, respectively). Crop nutrition through 100 % RDF + 5 t biocompost showed the highest pearl millet grain yield, but the same treatment had highest residual N and P in soil, as this treatment received plant nutrition through both organic and inorganic sources of fertilizers, which allowed the uptake of more N and P by means of crop yield and at the same time allowed sustainable residual N and P. Srivastava et al. (2015) reported an experiment of integrated nutrient management, a treatment of 100 % RDF + FYM at 10 t ha^{-1} + $ZnSO_4$ at 25 kg ha^{-1} + S at 25 kg ha^{-1} showed statistically equal yield to that of whole inorganic fertilizer treatment i.e. 150 % RDF. Meanwhile the integrated nutrient treatment indicated the highest residual available nutrients over whole inorganic or organic fertilizer treatments. It could be supposed that is more sustainable to use integrated nutrient/nitrogen approach over total inorganic fertilizer use for long term soil fertility and sustainability of soils.

In case of planting methods, transplanting of pearl millet indicated highest residual elemental N (225.88 kg ha^{-1}) and P (41.38 kg ha^{-1}) over drilled planting method (214.41 and 40.65 kg ha^{-1}, respectively). Drilled pearl millet showed highest grain yield over transplanted, hence the nutrient mining of N and P through drilled pearl millet was more evident, and this may be the reason why the residual N and P in transplanted pearl millet was higher.

Conclusions

The present study aimed to test the feasibility of late transplanted summer pearl millet under prolonged *rabi* season for three growing seasons. The premature heading of bajra was observed up to 8-10 % during all the three years, the possible causes for premature heading are late nitrogen availability, weather conditions, the thickness of the seedlings, root pruning and seedling age at transplanting. Treatment wise, as the dose of biocompost increased, the premature heading was increased in transplanted pearl millet. From the pooled data of three years, the present study demonstrated that integrated use of biocompost and chemical fertilizer (100 % RDF + 5 t biocompost) showed increased growth, yield contributing characters, yield, economics, available nutrients and quality of summer pearl millet and resulted sustainable from an economic and residual nutrient point of view. Application of 100 % RDF

+ 5 t biocompost was found at par with application of 75 % RDN + 25 % RDN through biocompost for grain yield of first three years and in pooled mean and first two years of straw yield. Comparatively, late transplanted summer pearl millet was not feasible to grow over timely drilled pearl millet as it had reduced pearl millet grain yield by 6.07 % and also reduced the net profit by 72.46 US $ ha^{-1}. But overall it was feasible to grow late transplanted pearl millet as it has reached up to the yield of 31.5 q in prolonged *rabi* season condition for brining summer season well in time.

References

Chander G, Wani SP, Sahrawat KL, Kamdi PJ, Chitendra KP, Pal DK, Mathur TP, 2013. Balanced and integrated nutrient management for enhanced and economic food production: case study from rainfed semiarid tropics in India. Arch Agron Soil Sci 59: 1643-1658

Charyulu KD, Moses SD, Bantilan C, Borikar ST, Gupta SK, Rai KN. 2016, Pearl millet technology adoption and impact study in Maharashtra. Research report 71.Patancheru 502 324. Telangana, India: International Crops Research Institute for the Semi-Arid Tropics. 76 pp. ISBN 978-92-9066-581-6

Chauhan M, Kumar D, Kumawat AK, Gudadhe NN, Hanwat R, 2016. Economics of summer pearl millet as influenced by transplanting dates and nitrogen levels. Multilogic in Sci 5(15): 30-32

Chouhan M, Gudadhe NN, Kumar D, Kumawat AK, Kumar R, 2015. Transplanting dates and nitrogen levels influences on growth, yield attributes, and yield of summer pearl millet. The Bioscan10(3): 1295-1298

Chudasama VN, Patel VJ, Patel PK, Patel BD, 2017. Feasibility of transplanting *rabi* maize (*Zea mays* L.) varieties to varying age of seedling under middle Gujarat conditions. J Pharmacog and Phytochem 6(5): 34-37

Deshmukh SP, Patel JG, Patel AM, 2013. Ensuing economic gains from summer pearl millet (Pennisetum glaucum L.) due to different dates of sowing and land configuration. African J Agril Res 8(49): 6409-6415

Eastin JD, 1972. Photosynthesis and translocation in relation to plant development. In: Sorghum in the seventies, Rao, N. G. P. and House L. R., (Eds), Oxford and IBH publishing Co., New Delhi, India, pp. 214-246

Evenson RE, Gollin D, 2003. Assessing the impact of the green revolution, 1960 to 2000. Science 300: 758–762

Fisher RA, Turner NC, 1978. Plant productivity in the arid and semiarid zones. Ann Rev Plant Physiol 29: 277-317

Gomez KA, Gomez AA, 1983. Statistical Procedures for Agricultural Research.: John Wiley & Sons, New York.

Gudadhe Nitin, Dhonde MB, Hirwe NA, Thete NM. 2016. Crop energy balance study of cotton-chickpea cropping sequence under organic and inorganic fertilizer sources in western Maharashtra. Legume Res 39 (1): 79-85

Gudadhe Nitin, Dhonde MB, Hirwe NA, 2015. Effect of integrated nutrient management on soil properties under cotton chickpea cropping sequence in vertisols of Deccan plateau of India. Indian J Agric Res 49 (3): 207-214

Jackson ML. 1973. Soil chemical analysis, Prentice Hall of India Pvt. Ltd. New Delhi, India.

Khairwal, IS, Ram, C and Chhabra, AK, 1990.Millet seed production and technology.Daryaganj, New Dehli.

Mapfumo S.,Chiduza C., Young EM, Murungu FS and Nyamudeza P. 2007. Effect of cultivar, seedling age and leaf clipping on establishment, growth and yield of pearl millet (Pennisetumglaucum) and sorghum (Sorghum bicolor) transplants, South African J Plant & Soil, 24(4):202-208. DOI: 10.1080/02571862.2007.10634810

Moharana PC, Sharma BM, Biswas DR, 2017. Changes in the soil properties and availability of micronutrients after six-year application of organic and chemical fertilizers using STCR-based targeted yield equations under pearl millet-wheat cropping system.J Plant Nutr 40: 165-176

Murungu FS, Nyamudeza P, Mugabe FT, Matimati I, Mapfumo S, 2006. Effect of seedling age on transplanting shock, growth and yield of pearl millet (Pennisetum glaucum) varieties in semi arid Zimbabwe. J Agron 5(2): 205-211

Oswald A, Ransom JK, Kroschel J, Sauerborn J, 2001. Transplanting maize and sorghum reduces Striga hermonthica damage. Weed Sci 49: 346-353

Okamoto M, Okada K, Watanabe T, Ae N, 2003. Growth responses of cereal crops to organic nitrogen in the field. Soil Sci and Plant Nutr 49: 445-452

Page AL, Miller RH, Keeney DR, 1982. The methods of soil analysis.Part-2.Chemical and microbiological properties, 2nd edition, pp. 1159. Madison, WI: American Society of Agronomy. Inc./Soil Soc. Amer. Inc.

Parkinson JA, Allen SE, 1975. A wet oxidation procedure for determination of N and other mineral nutrients in biological material.Commun Soil Sci Plant Anal 6: 1–11

Patil, AS, Patel HK, Chauhan NP, 2014. Yield, quality and monetary returns of summer pearl millet (Pennisetumglaucum L.) as influenced by integrated nitrogen management and sowing methods.Crop Res 47(1-2): 24-28

Rathore SS, Gautam RC, 2003. Response of direct seeded and transplanted pearl millet (Pennisetum glaucum) to nitrogen, phosphorus and biofertilizers in intercropping system. Indian J Agron 48(3): 153-155

Selvaraju R, Gommes R, Bernardi M, 2011. Climate science in support of sustainable agriculture and food security. Climate Res 47(1/2): 95–110

Singh D, Baghel RS, Rajput RL, Kushwah SS, Rawat GS, 2017. Influence of seedling age and plant geometry on yield and uptake of nutrients in transplanted pearl millet under late sown condition. Technofame 6(1): 14-152

Singh R, Singh DP, Tyagi PK, 2003. Effect of azotobacter, farmyard manure and nitrogen fertilization on productivity of pearl millet hybrids (Pennisetum glaucum (L) r. br) in semiarid tropical environment. Arch Agron Soil Sci 49: 21-24

Singh RRT, Choudhary GL, Gupta AK, 2013. Effect of integrated nitrogen management on nutrient uptake, quality, economics and soil fertility of pearl millet under rainfed conditions. Elixir Agril 54: 12373-12375

Srivastava HS, Singh RP, 1999. Nitrogen nutrition and plant growth. Oxford: IBH Publishing.

Srivatsava PK, Sankar GRM, P Kumar V, Singh SP, Rani N, Singh A, Agarwal VK, 2015. Effects of organic and inorganic fertilizers on soil and plant nutrients and yields of pearl millet and wheat under semiarid inceptisols in India. Commun Soil Sci Plant Anal 46: 2595-2614

Wade B, 2009. Increasing crop productivity through nitrogen technologies. In: Proceedings of the Fertilizer Association of India Annual Seminar on Fertilizer Policy for Sustainable Agriculture; 2009 Dec 3–5; Hyderabad, India: The Fertilizer Association of India. p. 1–9

Waters L, Burrows RL, Bennet MA, Schoenecker J, 1990. Seed moisture and transplant management techniques influence sweet com stand establishment, growth, development and yield. J Am Soc Hort Sci 8: 60-68

Yadav OP, 2011. Project Coordinator Review (Pearl millet) All India Coordinated Pearl Millet Improvement Project Workship, Hisar 12-14 March 2011 pp. 1-9