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Studies on the yield maximization of pearl millet (*Pennisetum glaucum* L.) hybrid Phule Aadishakti through fertilizer equations of STCRC

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Abstract
An experiment entitled "Studies on the yield maximization of pearl millet (*Pennisetum glaucum* L.) hybrid Phule Aadishakti through fertilizer equations of STCRC" was conducted during *kharif* 2023 at Bajra Research Scheme, College of Agriculture, Dhule. The experiment consisted of seven treatments laid out in a randomized block design with three replications. The treatments viz., (T_1) application of fertilizer as per RDF (60:30:30 kg NPK ha^{-1}), (T_2) application of fertilizer as per soil test (75:30:15 kg NPK ha^{-1}), (T_3) application of fertilizer for 40 q ha^{-1} yield target (60:68:33 kg NPK ha^{-1}), (T_4) application of fertilizer for 45 q ha^{-1} yield target (77:85:41 kg NPK ha^{-1}), (T_5) application of fertilizer for 50 q ha^{-1} yield target (93:102:49 kg NPK ha^{-1}), (T_6) application of fertilizer for 55 q ha^{-1} yield target (110:119:58 kg NPK ha^{-1}), (T_7) application of fertilizer for 60 q ha^{-1} yield target (126:135:65 kg NPK ha^{-1}), were used in this experiment. The different yield target based fertilizer application treatments significantly influenced the growth and yield of pearl millet. The growth parameters of pearl millet like plant height differed significantly due to different yield target based fertilizer application treatments. Among the different treatments, the application of fertilizer for 60 q ha^{-1} yield target (T_7) produced higher growth attributes than other yield target based fertilizer application treatments. But it was statistically at par with the application of fertilizer for 55 q ha^{-1} yield target (T_6). The significant effect on the growth character of the plant was noticed due to different yield target based fertilizer applications, which resulted in enhanced yield and yield contributing characters viz., number of total tillers plant^{-1}, number of effective tillers plant^{-1}, ear head length (cm), ear head girth (cm), 1000 grains weight (g), grain and straw yield (q ha^{-1}), respectively. Among different yield target based fertilizer application treatments, the application of fertilizer for 60 q ha^{-1} yield target (T_7) produced significantly higher grain and straw yield of pearl millet (46.08 q ha^{-1} and 91.86 q ha^{-1}) respectively, than other yield target based fertilizer application treatments and it was found to be at par with the application of fertilizer for 55 q ha^{-1} yield target (T_6). The gross and net returns were highest with the application of fertilizer for 60 q ha^{-1} yield target (T_7) (₹ 120707 ha^{-1} and ₹ 80371 ha^{-1}), respectively than the rest of the treatments and found to be at par with the application of fertilizer for 55 q ha^{-1} yield target (T_6). Benefit-cost ratio was also the highest in the application of fertilizer for 60 q ha^{-1} yield target (T_7) (2.99) as compared to the other treatments followed by the application of fertilizer for 55 q ha^{-1} yield target (T_6) and the application of fertilizer as per soil test (T_2).

Keywords: STCRC, Yield target, pearl millet, Fertilizer

Introduction
Pearl millet (*Pennisetum glaucum* L.) commonly known as bajra, Kumbu is a multipurpose cereal crop belonging to the family Poaceae. It is considered to be a poor man's food as it provides staple food for the poor in a short period. It is the world's hardiest warm season cereal crop. It's generally grown as a rainfed crop during *kharif* season. Globally it ranks sixth after rice, wheat, maize, barley and sorghum in terms of area and share 42 per cent of total world production (Baby *et al*., 2020) [4].

It is one of fourth most important food crop in India after rice, wheat and sorghum and well adapted to drought, low soil fertility and acidic soil conditions (Choudhary *et al*., 2014) [7]. Pearl millet is an indispensable arid and semiarid crop of India cultivated as dual-purpose crop, grains are used for human consumption and its straw as cattle feed.

It's straw is an important component of livestock ration during the dry period of the year. (Khairwal *et al*., 2007) [9].

Pearl millet contains Vitamin A, Vitamin B, Folic acid, magnesium, and other major, minor as well as micro nutrients. Pearl millet grain is nutritionally better than many cereals as it is good source of protein having higher digestibility (12.1%), fats (5%) and high levels of iron, zinc and insoluble dietary fiber and is the major source of dietary carbohydrates (69.1%) in the human diet (Kumar *et al*., 2021) [10].

The productivity of pearl millet in Maharashtra is low as compared to India due to several factors viz. variation in soils, erratic and scanty nature of rainfall, improper method of sowing, poor plant stand, low and imbalance use of inorganic fertilizer and scanty use of organic manures. Among the various reasons, less fertilization is the main reason for low productivity of pearl millet. On an average production of tones of dry fodder removes 9.4 kg N, 1.45 kg P, 1.4 kg K, 4.61 kg Ca, 2.65 kg Mg and 1.85 kg S (Bose and Balakrishnan, 2001) [5]. It is therefore, necessary to increase the production and productivity of pearl millet by adopting scientific innovations.

Application of imbalanced and/or excessive nutrients led to declining nutrient-use efficiency making fertilizer consumption uneconomical and producing adverse effects on atmosphere (Aulakh and Adhya, 2005) [2] and groundwater quality (Aulakh *et al*., 2009) [3] causing health hazards and climate change.

The soil test crop response (STCR) are cost effective and plant need based approaches. The STCR approach provide principles and tools for supplying crop nutrients as and when needed to achieve higher yield. The STCR approach not specifically aim to either reduce or increase fertilizer use. Instead, they aim to apply nutrients at optimal rates and time to achieve higher yield and high efficiency of nutrient use by the crop, leading to more net returns per unit of fertilizer applied. Soil test calibration permits balanced fertilization through right kind and amount of fertilizers. In this regard, targeted yield approach had been found to be beneficial recommending balanced fertilization considering the soil available nutrient status and crop needs.

Integrated nutrient management strategies that include site specific knowledge of crop nutrient requirements, soil nutrient supply, and recovery efficiency of applied fertilizer, are required to sustain high yields and maintain or build up soil fertility at a level that ensures 3 maximum efficiency from nutrient inputs (Sharma *et al*., 2015) [19]. Several approaches have been used for fertilizer recommendation based on chemical soil test so as to attain maximum yield per unit of fertilizer use. Among the various approaches, the target yield approach (Ramamoorthy *et al*., 1967) [15] has found popularity in India.

Targeted yield approach not only estimates soil test based fertilizer dose but also the level of yield the farmer can achieve with that particular dose. The basic data required for formulating fertilizer recommendation using this approach are nutrient requirement for a unit grain yield, nutrient contribution from soil i.e., nutrient supplying capacity of soil and the nutrient contribution from fertilizer i.e., recovery efficiency of fertilizer nutrient. Quantitative fertilizer requirements based on this approach have been estimated for specific yield target of crops like rice and wheat (Ahmed *et al*., 2002) [1]. Recommendations based on Soil Test Crop Response Correlation concept are more quantitative precise and meaningful because combined use of soil and plant analysis is involved in it. It gives a real balance between applied nutrients and the available nutrients already present in the soil.

Hence, need based estimation of N, P and K correlating their requirement with specific yield depending on their native soil status may fit to balanced application of NPK fertilizers. The 'yield equation' (YE) is considered as a soil and fertilizer based precision farming strategy to meet nutrient demands for a specified yield. Therefore, it is important to study the response of bajra to manure and fertilizer application, estimate the nutrient requirement of bajra and develop quantitative relationship to estimate requirement for target yield of bajra.

Materials and Methods

A field experiment entitled, "Studies on the yield maximization of pearl millet (*Pennisetum glaucum* L.) hybrid Phule Aadishakti through fertilizer equations of STCRC" was carried out during the *kharif* season of 2023. The field experiment was conducted at Bajra Research Scheme, College of Agriculture, Dhule, M.S. (India).

The Bajra Research Scheme Farm is located in Northern Maharashtra's Agro-climatic Zone-6, often known as the scarcity zone. It is located at 20.4 ºN latitude and 74 ºE longitude. The elevation is 258 meters above mean sea level. It is located at the intersection of National Highways No. 3 and 6. This location has a subtropical climate and is located in the northern subtropics. Monsoon season typically begins in the third week of June and ends at the end of September, with an average annual rainfall of 608.3 mm at College of Agriculture, Dhule. This is largely due to the South-West monsoon. The majority of rain falls on 34 to 40 rainy days each year. The mean annual maximum and minimum temperature and evaporation ranges from 46.6 ºC and 6.8 ºC, 18.0 mm and 0.7 mm respectively. The maximum sunshine hours are 8.70 hrs. Some climatic criteria, such as relative humidity and sunlight hours, were more or less favourable for *kharif* pearl millet growth and development in 2023. Also, the rainfall distribution obtained throughout crop development was uniform. Off season rains of 42.4 mm were received during the *kharif* season.

In general, the weather conditions were found favourable for normal crop growth and development. The experiment had seven treatment, and three replications was set up in a randomized block design. The seven treatments included T_1-Recommended dose of fertilizer as per the treatment (60:30:30 kg NPK ha^{-1}),T_2-Fertilizer as per soil test, T_3 -Fertilizer for 40 q ha^{-1} yield target, T_4 -Fertilizer for 45 q ha^{-1} yield target, T_5 -Fertilizer for 50 q ha^{-1} yield target, T_6 -Fertilizer for 55 q ha^{-1} yield target, T_7 -Fertilizer for 60 q ha^{-1} yield target. Where, 5 t ha^{-1} FYM and Azospirillum biofertilizer 25 g kg^{-1} of seed common to all treatment.

Table 1: Treatment details

Tr. No.	Treatment Details
T_1	Recommended dose of fertilizer as per the treatment (60:30:30 kg NPK ha^{-1})
T_2	Fertilizer as per soil test
T_3	Fertilizer for 40 q ha^{-1} yield target
T_4	Fertilizer for 45 q ha^{-1} yield target
T_5	Fertilizer for 50 q ha^{-1} yield target
T_6	Fertilizer for 55 q ha^{-1} yield target
T_7	Fertilizer for 60 q ha^{-1} yield target

Yield Target Equation for Pearl millet

1. FN = 3.31 T-0.38 SN
2. FP_2O_5 = 3.38 T-4.11 SP
3. FK_2O = 1.65 T-0.06 SK

Where, FN, FP_2O_5, FK_2O= Fertilizer N, P_2O_5, FK_2O (kg ha^{-1})

T = Yield Target (q ha^{-1})

SN, SP, SK = Soil available nitrogen, phosphorus, potassium (kg

ha^{-1})

Note: Initial available status of N, P, K in soil is used for calculations of fertilizer doses through the yield target equation mentioned

The plant height was measured from the base of the plant *i.e.*, ground level to the tip of the base of fully opened upper leaf of the batch of five tagged plants selected at random in each net plot of all the three replications at 30,45,60,75 and at harvest. An average value for each plot was calculated and documented. The length of the ear head was measured from the base to the tip of the ear head on the main tiller at harvest using a measuring scale, and the mean was calculated. The maximum thickness at the centre of the ear head on main tiller was measured from the randomly selected five plants at harvest with the help of 'vernier caliper' and mean was calculated. During harvest, the effective number of tillers plant-1 was calculated from randomly selected five plants and mean was calculated. During harvest, total number of tillers calculated from randomly selected five plants and mean was calculated. One thousand pearl millet grain samples were counted from the net plot and its weight was recorded.

Grain yield per net plot was recorded after threshing all the ear heads from each net plot and converted into hectare basis.Straw yield per net plot was obtained by using a weighing balance on field after harvesting when stover become totally dry.

The gross monetary returns of each treatment were worked out by converting grain and straw yield of maize into money value at the prevailing market price.

The cost of cultivation of each treatment of maize was worked out by considering the actual amount incurred for purchase of different, urea, nano urea manure, hired charges for machineries and implements, wages of hired labour, cost of seeds, irrigation charges, foliar sprays of organic substances and so on.

The net monetary return of each treatment was calculated by subtracting the cost of cultivation from gross monetary return.

The formula used is as under

Net monetary returns=Gross Monetary Returns-Cost of Cultivation

Benefit: Cost ratio was worked by dividing gross monetary returns of different treatment from their corresponding value of cost of cultivation. The formula used is given below:

$$\text{Benefit: cost ratio} = \frac{\text{Gross Monetary Returns (₹ ha}^{-1}\text{)}}{\text{Cost of Cultivation (₹ ha}^{-1}\text{)}}$$

The data collected and analysis of data was carried out by "Analysis of Variance method" by Panse and Sukhatme, 1967 [14]. When the treatment differences were significant standard error (S.E.±) and critical difference (C.D.) were calculated at 5% probability level and when the treatment differences were not significant, only standard error was worked out.

Results and Discussion

Growth Studies

Data in a respect of plant height (cm) of pearl millet as influenced by various treatments at different growth stages were analyzed statistically and presented in Table 2. The results indicated that growth attributes evaluated in study were significantly influenced by treatments. The higher plant height (cm) of pearl millet was significantly influenced due to different treatment and various growth stages of crop. Among different treatments, application of fertilizer for 60 q ha^{-1} yield target (T_7) recorded the highest plant heights of 72.56 cm, 151.40 cm, 214.52 cm, 222.76 cm, and 226.33 cm at 30 DAS, 45 DAS, 60 DAS, 75 DAS and at harvest, respectively as compared to other treatments and it was found to be at par with application of fertilizer for 55 q ha^{-1} yield target (T_6) having plant height of 70.50 cm, 149.44 cm, 212.56 cm, 220.80 cm and 224.33 cm at 30 DAS, 45 DAS, 60 DAS, 75 DAS and at harvest, respectively. The mean plant height was found to be increased with advancement in age of crop and the highest plant heights was observed at harvest. Plant height increased at a modest rate up to 30 DAS and then accelerated to 60 DAS before slowing down as the plant transitioned from the vegetative to the reproductive phase. The increased plant height of pearl millet might be due to judicious application of all the nutrient sources and their efficient utilization. This might be due to the increase in availability of nutrients for plant growth which may have increased chlorophyll formation and photosynthesis. Increased plant height resulted in more nodes per plant which accommodated more leaves per plant. Again, nitrogen helped in rapid growth and development of plants as they help in photosynthesis and various plant biochemical processes that respond to growth rate thus resulting in improved overall growth of the plant. Similar results were reported by Saraswathi *et al.* (2015) [17]; Singh *et al.* (2021) [18]; Rani *et al.* (2022) [16].

Table 2: Plant height of pearl millet as influenced periodically by different treatments

Tr. No.	Treatments	Plant Height (Cm)				
		30 DAS	45 DAS	60 DAS	75 DAS	At harvest
T_1	Recommended dose of fertilizer (60:30:30 kg NPK ha^{-1})	66.27	139.23	202.35	210.59	214.57
T_2	Fertilizer as per soil test	67.27	140.90	204.02	212.26	216.37
T_3	Fertilizer for 40 q ha^{-1} yield target	68.63	143.53	206.65	214.89	218.67
T_4	Fertilizer for 45 q ha^{-1} yield target	68.87	144.73	207.85	216.09	220.00
T_5	Fertilizer for 50 q ha^{-1} yield target	69.33	145.48	208.60	216.84	221.83
T_6	Fertilizer for 55 q ha^{-1} yield target	70.50	149.44	212.56	220.80	224.33
T_7	Fertilizer for 60 q ha^{-1} yield target	72.56	151.40	214.52	222.76	226.33
	SE (m.) ±	0.96	1.67	1.81	1.77	1.40
	CD at 5%	2.96	5.16	5.58	5.46	4.33
	General mean	69.06	144.96	208.08	216.32	220.30

Yield contributing characters

The data presented in Table 4.4. showed that among different treatments, application of fertilizer for 60 q ha^{-1} yield target (T_7) produced significantly maximum number of total tillers $plant^{-1}$ (5.22), number of effective tillers $plant^{-1}$ (4.04), ear head length of 26.51 cm and ear head girth of 12.37 cm but it remained at par with the application of fertilizer for 55 q ha^{-1} yield target (T_6) that produces 5.11 total tillers $plant^{-1}$, 3.66 effective tillers $plant^{-1}$, ear head length of 26.19 cm and ear head girth of 12.27 cm.

Table 3: Total tillers, Effective tillers plant^{-1}, Ear head length (cm), Ear head girth (cm) and 1000 grain weight (g) of pearl millet at harvest as influenced by different treatments

Tr. No.	Treatments	Number of Tillers Plant^{-1}		Ear Head Length (Cm)	Ear Head Girth (Cm)	1000 Grain Weight (G)
		Total	Effective			
T_1	Recommended dose of fertilizer (60:30:30 kg NPK ha^{-1})	3.57	2.97	25.18	11.43	11.18
T_2	Fertilizer as per soil test	3.94	3.07	25.36	11.60	11.37
T_3	Fertilizer for 40 q ha^{-1} yield target	4.18	3.11	25.80	11.77	11.60
T_4	Fertilizer for 45 q ha^{-1} yield target	4.35	3.26	25.97	12.05	12.00
T_5	Fertilizer for 50 q ha^{-1} yield target	4.67	3.41	26.07	12.11	12.11
T_6	Fertilizer for 55 q ha^{-1} yield target	5.11	3.66	26.19	12.27	12.18
T_7	Fertilizer for 60 q ha^{-1} yield target	5.22	4.04	26.51	12.37	12.24
	SE (m.) ±	0.17	0.18	0.11	0.07	0.034
	CD at 5%	0.52	0.58	0.34	0.24	0.106
	General mean	4.43	3.36	25.87	11.94	11.81

Increase in the yield attributes might have been owing to better utilization of resources under improved N supply, as it is an integral part of proteins the building blocks of plant. The improvement in all these yield attributes might have been due to favourable effect of nitrogen application on physiological parameters resulting in the increase of photosynthetic efficiency and subsequent translocation of photosynthates into reproductive organs. This might be due to the fact that application of higher dose of fertilizers led to higher availability of nutrient that promoted the growth and development and enhances the nutrient availability, uptake and translocation and ultimately resulted in increasing yield attributes like ear head length, ear head girth. Rani *et al.* (2022) [16].

The probable reason for the increase in test weight is due to the higher availability of nitrogen, which might be attributed to the better filling of grains resulting in bold sized seeds and consequently the highest test weight. Similar results were reported by Saraswathi *et al.* (2015) [17]; Singh *et al.* (2021) [18]; Rani *et al.* (2022) [16].

Table 4: Grain yield (q ha^{-1}), stover yield (q ha^{-1}) and Economics (₹ ha^{-1}) of pearl millet as influenced by different treatments

Tr. No.	Treatments	Grain yield (q ha^{-1})	Stover Yield (q ha^{-1})	Gross returns (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
T_1	Recommended dose of fertilizer (60:30:30 kg NPK ha^{-1})	30.23	57.77	79049	30044	49005	2.63
T_2	Fertilizer as per soil test	35.49	65.77	92680	31995	60685	2.90
T_3	Fertilizer for 40 q ha^{-1} yield target	38.19	70.90	99720	35196	64524	2.83
T_4	Fertilizer for 45 q ha^{-1} yield target	39.24	80.04	102902	36957	65945	2.78
T_5	Fertilizer for 50 q ha^{-1} yield target	40.21	82.70	105495	39390	66105	2.68
T_6	Fertilizer for 55 q ha^{-1} yield target	43.97	83.27	114925	39572	75353	2.90
T_7	Fertilizer for 60 q ha^{-1} yield target	46.08	91.86	120707	40336	80371	2.99
	SE (m.) ±	1.81	2.73	4546.38	-	4546.38	-
	CD at 5%	5.57	8.41	14010.00	-	14010.00	-
	General mean	39.06	76.04	102211	36213	65998	2.82

Yield studies

The grain and straw yield of pearl millet (q ha^{-1}) which recorded significantly maximum (46.08 and 91.86 q ha^{-1}, respectively) with application of fertilizer for 60 q ha^{-1} yield target (T_7) as compared to other treatments of targeted yield based fertilizer application treatments, but was found to be statistically at par with application of fertilizer for 55 q ha^{-1} yield target (T_6) for grain yield only with value 43.97 q ha^{-1}.

Increase in grain yield under the pearl millet fertilized as per STCR with 60 q ha^{-1} yield target (T_7) followed by pearl millet fertilized as per STCR with 55 q ha^{-1} yield target (T_6). This might be due to increase in fertilizer dose of fertilizer as per yield target equation of STCRC formulated for pearl millet crop and balanced fertilization through STCR increased crop yield probably by making more nutrients available to plants which in turn increased crop growth and yield attributes which increased the grain and fodder yield.

The similar trends were noticed from the researches conducted on yield target based fertilizer recommendation on pearl millet, finger millet and paddy by Shetty *et al.* (2018) [21], Chandrasekhar *et al.* (2020) [6], Narmada *et al.* (2023) [13], Murthy *et al.* (2023) [11].

Higher stover yield under the pearl millet fertilized as per STCR with 60 q ha^{-1} yield target treatment (T_7) followed by decreasing order of treatments *i.e.*, T_7> T_6> T_5> T_4> T_3> T_2> T_1. This might be due to adequate supply of NPK through inorganic sources that played vital role in physiological and developmental processes in plant life and also higher values of growth and yield attributes and balanced fertilization through STCR increased crop yield probably by making more nutrients available to plants which in turn might have accelerated the growth processes that in result increased straw yield in treatment applied higher dose of fertilizer as per yield target.

Similar results obtained from the research conducted on targeted yield based fertilizer recommendation on pearl millet, finger millet, paddy by Shetty *et al.* (2018) [21]; Chandrasekhar *et al.* (2020) [6]; Narmada *et al.* (2023) [13]; Murthy *et al.* (2023) [12].

Economics (₹ ha^{-1})

Among various yield target based fertilizer application treatments, the maximum cost of cultivation, gross and net monetary returns (₹ 40336, ₹ 120707 and ₹ 80371 ha^{-1}, respectively) was found with the application of fertilizer for 60 q ha^{-1} yield target (T_7). The benefit-cost ratio was considerably higher (2.99) with the application of fertilizer for 60 q ha^{-1} yield target (T_7) than the rest of the treatments under study which was followed by two treatments *viz.*, the application of fertilizer for 55 q ha^{-1} yield target (T_6) and the application of fertilizer as per

soil test (T_2) with benefit-cost ratio of 2.90. It was found to be an economically better treatment.

The highest net return was mainly because of higher yield of grains and straw. The differences in the B:C ratio is attributed to yield differences and varying costs when different dose of fertilizers were added as per treatments requirement. It is evident that fertilizer application as per required targeted yield can be used for more profitable income. Similar results are also reported by Sekaran *et al.* (2019) [20], Goyal *et al.* (2020) [8], Murthy *et al.* (2023) [11].

Conclusion

The following conclusions are drawn from the present investigation

1. The integrated fertilizer prescription equations found beneficial and valid for achieving the higher pearl millet yield for Dhule region. The fertilizer equation for pearl millet was valid upto 40 q ha^{-1} of targeted yield.
2. The maximum attainable yield for grains was obtained upto 46.08 q ha^{-1} under fertilizer for 60 q ha^{-1} yield target, which was found statistically at par with fertilizer for 55 q ha^{-1} yield target having grain yield of 43.97 q ha^{-1}.
3. The STCR approach for targeted yield obtained significantly higher values of growth characters, yield contributing characters, yield, economics of pearl millet.

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