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# VERIFICATION OF SOIL TEST CROP RESPONSE BASED FERTILIZER RECOMMENDATIONS FOR TARGETED YIELDS OF PEARL MILLET IN SEMI-ARID SOUTH WESTERN ZONE OF HARYANA

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## SUMMARY

The soil test crop response based fertilizer prescription equations under integrated nutrient supply for achieving the targeted yields of pearl millet were verified for irrigated farming areas at different farmers' fields during *kharif* 2020 and 2021. Seven fertilizer treatments were implemented which included control; farmers practice (FP); generalized package recommendations (PR), STCR recommendations for 30 & 35 q/ha (TY-30 & TY-35) 3 grain yield target with fertilizers alone; and with fertilizer and FYM (TY-30 FYM & TY-35 FYM under irrigated conditions. The results showed that mean grain yield was highest for TY-35 FYM in irrigated for both the years followed by TY-35, TY-30 FYM, TY-30, PR, FP and Control. The response to fertilizer application also followed the same trend. Under irrigated conditions, the yield targets of 30 & 35 q/ha were achieved within deviations of -5.0 to +2.1 and -5.3 to +0.7 per cent, respectively. For integrated plant nutrient supply, it varied between -3.7 to + 3.2 and -3.6 to + 0.6 per cent for yield targets of 30 & 35 q/ha, respectively. These deviations (±10 %) in the yield indicated the validity of fertilizer prescription equations for targeted yields of pearl millet under irrigated farming areas of Hisar district. The economics of the fertilizer application also indicated that marginal B:C ratio of the two years varied between 3.42 to 7.22 and 4.63 to 5.49 for different farmers field locations and years (*kharif* 2017 and 2018) of Hisar district of Haryana under irrigated conditions, respectively. The marginal B:C ratio under different treatments are viable and remunerative. Therefore, farmers should go for 25 & 18 q/ha seed yield target under irrigated and dryland areas, respectively. Also, 20 & 15 q/ha seed yield target can be adopted under resource constraint situations.

**Key words:** Pearl millet, target yield equation, verification, Economics, Haryana

Pearl millet-wheat is the dominant cropping system of north-west and central plains of India and south-west part of Haryana. This cropping system is followed in an estimated area of 226.24 lakh hectares in India and 20.87 lakh hectares in Haryana (Yadav and Suba Rao, 2002). In arid and semi-arid regions, pearl millet can extract high yield as compared to other crops. Also wheat contributes 13.3 % towards national production from 9% area of the country (Kumar *et al*., 2012). Thus for sustaining and increasing yield of crops, the major challenge confronting us is to manage the variability in soil nutrient supply which may arise due to imbalance and injudicious use of inorganic fertilizers only.

Phosphorous and potassium are the next major nutrient required by the plant after nitrogen. Inspite of high fixation capacity and low recovery of added P, its significant build up in soils has been observed (Brar *et al*., 2004) and present in soil as insoluble or fixed form. Total soil-P in soil ranges from 0.01 to 0.30% and occurs in three forms soil solution P, organic P and inorganic P. Organic P, mainly confined to the surface layer, is mineralized into inorganic forms. But, the plants mainly depend upon inorganic P forms for their P requirement.

Soil test crop response (STCR) is a base for prescription of the right amount of fertilizers to the crops (Kumar et al., 2021 and Kumar et al., 2020). Balanced fertilization is of prime importance for maintaining the soil health in terms of fertility and productivity that ultimately leads to environmental protection (Das *et al*., 2015). The widespread multi-nutrient deficiencies due to imbalanced fertilization have induced in many parts of India (Bindraban *et al.*, 2015). Improving nutrient use efficiency is considered synonymous to develop a rationale efficiency of fertilizer use. No single dose of plant nutrient applied through inorganic fertilizers, organic manures, crop

residues or bio-fertilizers can meet the entire nutrient requirement of a crop in modern intensive agriculture (Gangwar *et al.,* 2016; Udayakumar and Santhi, 2017; Sekaran *et al.,* 2018). Thus there is an urgent need to adopt the integrated plant nutrient supply approach (IPNS) which is practicable, economically viable, socially acceptable and ecologically sound. Adaptation of STCR based integrated plant nutrition system (STCR-IPNS) can restore and sustain soil fertility and crop productivity, prevent secondary and micronutrient deficiencies, economize the fertilizer use and improvement in nutrient use efficiency and create favourable effect on the physical, inorganic and biological health of soils (Udayakumar and Santhi, 2017; Singh *et al.,* 2012). So, there is a balanced supply of required quantities of nutrients to the crop thereby avoiding the over usage or under usage of fertilizers. This prevents environmental hazards and results in higher net returns. Based on resource availability of the farmer, the fertilizer requirement could be lowered or increased by lowering or increasing the yield target taking into consideration of the genetic and area potential of the crop or varieties (Dey, 2015). Crop requirements are satisfied to produce the highest economic yields, ensure the quality of the produce and avoid excessive levels of nutrients (Boldea *et al.,* 2015). To enhance farm profitability under different soil-climatic conditions, it is necessary to generate information on optimum nutrient doses for various crops.

## MATERIALS AND METHODS

The soil test based fertilizer prescription equations for targeted yield of pearl millet under integrated plant nutrient supply were tested at four farmers' fields under irrigated conditions during k*harif* 2017 and 2018 in pearl millet growing areas of Hisar district. Before laying out the experiment, composite surface (0-15 cm) soil samples were taken from the fields of farmers' processed in the laboratory and analyzed for texture, pH and electrical conductivity using standard methods. The samples were also analyzed for organic carbon and available nitrogen (N), phosphorous (P) and potassium (K) using standard methods. Seven fertilizers and FYM treatments were applied in each field comprising of control, farmers' practice (FP), general package recommendations of fertilizers (PR), soil test based fertilizer dose for 30 q/ha (TY-30 and TY) and 35 q/ha (TY-35) seed yield without FYM. In addition, there were two treatments in which fertilizers along with 15 t FYM/ ha were applied for 30 q/ha (TY-30 FYM) and 35 q/ha (TY-35FYM), respectively. The doses of fertilizers N, $P_2O_5$ and $K_2O$ for different yield targets were calculated by using soil test crop response based fertilizer prescription equations under integrated nutrient supply (STCR-IPNS) for targeted yield of pearl millet *(*RCH 773) developed during 2004-2006 by the Hisar centre of AICRP on "Soil Test Crop Response Correlations" which are as given below:

$$FN = 10.48\ T - 1.60\ SN - 0.13\ FYM\ (N)$$
$$FP_2O_5 = 4.39\ T - 5.64\ SP - 0.14\ FYM\ (P_2O_5)$$

where FN and F($P_2O_5$) are fertilizers N and $P_2O_5$ (kg/ha), respectively. T is seed cotton yield target (q/ha). SN and SP are the soil available N and P (kg/ha), respectively. FYM (N) and FYM ($P_2O_5$) are the N and $P_2O_5$ through FYM (kg/ha), respectively.

The doses of fertilizer N and $P_2O_5$ were reduced in TY 30 FYM & TY 35 FYM in comparison to TY 30 & TY 35 treatments depending upon the contents of nutrients and their efficiencies in FYM. The FYM was applied and well mixed in soils by ploughing about 10-15 days prior to sowing of the pearl millet. One half dose of N through urea and full dose of P through diammonium phosphate were applied as basal dose at the time of sowing, whereas, one half N was applied after 1st irrigation *i.e*. 21-25 days after sowing. Sowing of the seed was done with seed drill in the first week of July each year. The crop was raised up to maturity and the seed yield was recorded treatment wise. The response (kg/ha) of added nutrients was calculated by subtracting the yield of control from that of the fertilizer /and FYM treatments. The response yardstick (kg $kg^{-1}$) was calculated by dividing the response in a treatment by the total nutrient applied in the treatment. The net profit due to fertilizer application was calculated by subtracting the price of fertilizers applied from the total benefit from response. The marginal B:C was worked out by dividing the price of additional produce with the price of fertilizers.

## RESULTS AND DISCUSSION

### Physico-chemical properties of soil

Soil properties of the experimental sites at farmers' filed (Table 1) revealed that the pH of soils ranged from normal and alkaline in reaction varying between 7.3 and 8.0, non-saline with electrical

conductivity ranging from 0.23 to 0.59 dS/m and the soil texture varied from sandyloam to loam. The soils were low to medium in organic carbon (0.38 to 0.49 %), low in available N (112 to 140 kg/ha), medium to high in available P (10 to 20 kg/ha) and high in available K (225 to 325 kg/ha). The soil test values of different fields indicated considerable variations in organic carbon and available N, P & K. The doses of fertilizer nutrients and FYM applied in different treatments in the fields are presented in Table 2.

TABLE 2
Fertilizer doses ranges in different treatments in pearl millet (HHB 226) at farmer's field in different years

| S. No. | Treatment | Fertilizer nutrients (kg/ha) | |
|---|---|---|---|
| | | N | $P_2O_5$ |
| ***Kharif* 2020** | | | |
| 1. | Control | 0 | 0 |
| 2. | F.P. | 100-125 | 45-50 |
| 3. | P.R. | 150 | 60 |
| 4. | TY-30 | 90-124 | 19-64 |
| 5. | TY-35 | 143-176 | 41-86 |
| 6. | TY-30FYM | 68-102 | 4-49 |
| 7. | TY-35FYM | 121-154 | 26-71 |
| ***Kharif* 2021** | | | |
| 1. | Control | 0 | 0 |
| 2. | F.P. | 100-125 | 45-50 |
| 3. | P.R. | 150 | 60 |
| 4. | TY-30 | 90-135 | 64-75 |
| 5. | TY-35 | 143-188 | 86-97 |
| 6. | TY-30FYM | 68-113 | 49-60 |
| 7. | TY-35FYM | 121-166 | 42-82 |

## Grain yield of pearl millet

The grain yield of pearl millet obtained in various treatments at different locations for irrigated conditions in both the years ranged widely (Tables 3 and 4). The mean grain yield of the four sites in different villages in control varied from 1790 kg/ha to 1850 kg/ha during both years of study with pooled mean value of 1790 kg/ha during *kharif 2017 & 2018, respectively*. A perusual of data on soil test values in table 1 and crop yields in table 3 & 4 revealed that the yield in control varied in accordance to the inherent soil fertility status of the experimental sites at farmers' fields. The yield in F.P. treatment ranged from 2408 to 2661 kg/ha during 2017 and 2018 (pooled mean 2435 kg/ ha) under irrigated conditions indicating an improvement of yield by about 41.6 % in FP over control on pooled mean basis of two years for irrigated. The increase in yield in FP over control was due to the application of 100 to 125 kg N and 45-50 kg $P_2O_5$/ha in irrigated condition by the farmers at different locations (Table 2). The response to fertilizer application over control ranged from 679 to 811 kg/ ha (mean 745 kg/ha) in FP under irrigated condition at farmers' field of Hisar district, Haryana. The grain yield of pearl millet varied in PR treatment varied from 2706 to 2864 kg/ha (pooled mean 2785 kg/ha) under irrigated condition. The mean response in PR over control was 996 in pearl millet under irrigated condition. The improvement in yield and response in PR over FP was due to higher application of fertilizers in PR (Table 2). In PR treatment, 150 kg N and 60 kg $P_2O_5$ under irrigated condition, fertilizer nutrients were applied whereas lower doses of N and $P_2O_5$ without K were applied in FP treatment, thereby making strong case of balanced fertilizer application in PR treatment. The NPK consumption ratio is highly skewed towards N resulting in imbalanced and inadequate use of

TABLE 1
Physico-chemical properties of the soils of the farmers' fields

| S. No. | Village | Texture | pH (1:2) | EC (dS/m) (1:2) | Organic Carbon (%) | Available Nutrients (kg/ha) | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | N | P | K |
| ***Kharif* 2020** | | | | | | | | |
| 1. | Dhani Kutubpur I | SL | 8.0 | 0.28 | 0.49 | 140 | 20 | 325 |
| 2. | Dhani Kutubpur II | SL | 7.5 | 0.26 | 0.48 | 126 | 12 | 250 |
| 3. | Gyanpura | L | 7.7 | 0.23 | 0.45 | 119 | 20 | 280 |
| 4. | Haripur | SL | 7.6 | 0.35 | 0.41 | 126 | 15 | 205 |
| ***Kharif* 2021** | | | | | | | | |
| 1. | Khara Barwala | L | 8.0 | 0.30 | 0.42 | 133 | 12 | 265 |
| 2. | Kishangarh | L | 7.5 | 0.38 | 0.38 | 126 | 10 | 240 |
| 3. | Khabra | SL | 7.7 | 0.23 | 0.40 | 112 | 10 | 225 |
| 4. | Sadalpur | SL | 7.3 | 0.59 | 0.41 | 140 | 10 | 245 |

fertilizers particularly that of K resulting in mining of soils posing question mark to yield sustainability in pearl millet under irrigated conditions. Antil *et al.* (2015) reported that the area under low to medium category in available K in soils of Haryana was widespread to about 73 % which require K application through fertilizers for better crop yields and sustaining productivity and fertility of soils. The increase in yield due to application of higher levels of nutrients in balanced proportion was also reported by Antil and Singh 2007 and Hoshmani *et al.* (2013). The highest grain yield of pearl millet was recorded at all the sites under 35 q/ha STCR-IPNS (TY-35 FYM) ranging from 3395 to 3513 kg/ha (mean 3454 kg/ha) under irrigated condition. The mean response in TY-35 FYM over the control at all the sites was 1665 kg/ha in this treatment. The yield and response to fertilizer application in treatments where fertilizer alone were applied for 35 q/ha yield target, was slightly lower as compared to TY-35 FYM treatment. The mean yield in TY 35 was 3403 kg/ha under irrigated condition. The yield and response to fertilizer /and FYM application under targeted yield of 30 q/ha was moderate which were higher than FP and PR treatment and lower than TY-35/TY-35 FYM treatments. The mean yield in TY 30 and TY 30 FYM treatments on the basis of pooled data of two years was 2911 and 2977 kg/ha, with mean response of 1121 and 1188 kg/ha, respectively under irrigated condition. These results can well be interpreted by comparing the yield data (Table 3) and fertilizer nutrient doses at different experimental sites (Table 2). The application of N and $P_2O_5$ in TY-30 / TY-30 FYM treatments in different locations was lower than that in PR/TY-35/TY-35 FYM treatments. Thus, balanced application of these major nutrients resulted in higher yields in this treatment in comparison to FP & PR treatment under irrigated conditions. In PR treatment, blanket application of 150 and 60 kg N and $P_2O_5$ were applied in all the fields irrespective of the soil test values, whereas the application of these nutrients varied considerably for targeted yield treatments in different fields depending upon the soil test values of a specific field. Not only higher yield and response were obtained under STCR approach for 35 q/ha yield target but the precious fertilizer nutrients could also be saved in some fields.

TABLE 3

Mean seed yield, response, response yardstick, per cent deviations and economics of the fertilizer application in pearl millet (HHB 226) under irrigated conditions during *kharif* 2020 & 21

| S. No. | Treatment | Seed yield (kg/ha) | Response (kg/ha) | Response yardstick (kg/kg) | Per cent deviation | Cost of fertilizer (Rs.) | Profit (Rs) | Marginal B:C (Rs./Re) |
|---|---|---|---|---|---|---|---|---|
| ***Kharif* 2020** | | | | | | | | |
| 1. | Control | 1729 | | | | | | |
| 2. | F.P. | 2408 | 679 | 4.29 | - | 3301 | 11204 | 3.42 |
| 3. | P.R. | 2706 | 978 | 4.24 | - | 4268 | 16133 | 3.78 |
| 4. | TY-30 | 2878 | 1149 | 6.78 | -5.0 to -1.7 | 2859 | 18959 | 7.22 |
| 5. | TY-35 | 3371 | 1643 | 6.50 | -5.3 to -2.4 | 4389 | 27105 | 6.39 |
| 6. | TY-30FYM | 2941 | 1213 | 6.46 | -3.7 to +2.2 | 3484 | 20010 | 6.10 |
| 7. | TY-35FYM | 3395 | 1667 | 6.32 | -3.6 to -2.4 | 5014 | 27497 | 5.63 |
| ***Kharif* 2021** | | | | | | | | |
| 1. | Control | 1850 | | | - | | | |
| 2. | F.P. | 2661 | 811 | 5.11 | - | 3301 | 15815 | 4.81 |
| 3. | P.R. | 2864 | 1014 | 4.83 | - | 4268 | 19768 | 4.63 |
| 4. | TY-30 | 2944 | 1093 | 6.04 | -3.5 to +2.1 | 4264 | 21318 | 5.02 |
| 5. | TY-35 | 3434 | 1584 | 6.20 | -4.0 to +0.7 | 5798 | 30878 | 5.34 |
| 6. | TY-30FYM | 3013 | 1162 | 6.43 | -1.2 to +3.2 | 4889 | 22664 | 4.65 |
| 7. | TY-35FYM | 3513 | 1662 | 6.51 | -2.6 to +0.6 | 6012 | 32414 | 5.49 |
| ***Pooled mean* (2020 & 21)** | | | | | | | | |
| 1. | Control | 1790 | | | - | | | |
| 2. | F.P. | 2535 | 745 | 4.7 | - | 3301 | 13510 | 4.12 |
| 3. | P.R. | 2785 | 996 | 4.5 | - | 4268 | 17951 | 4.21 |
| 4. | TY-30 | 2911 | 1121 | 6.4 | -5.0 to +2.1 | 3562 | 20139 | 6.12 |
| 5. | TY-35 | 3403 | 1614 | 6.4 | -5.3 to +0.7 | 5094 | 28992 | 5.87 |
| 6. | TY-30FYM | 2977 | 1188 | 6.4 | -3.7 to +3.2 | 4187 | 21337 | 5.38 |
| 7. | TY-35FYM | 3454 | 1665 | 6.4 | -3.6 to +0.6 | 5513 | 29956 | 5.56 |

These results are in line with those reported by Gudadhe *et al* (2013), Manjunatha *et al.* (2014) and Katharine *et al* (2013), who reported the superiority of STCR based fertilizer recommendations over farmer's practices and blanket recommendations. Milap-chand *et al*. (2006) validated the fertilizers prescription equation for mustard and rapeseed and observed the higher yield under fertilizer application based targeted yield treatments. Also, Gudadhe *et al.*, (2015) showed that the application nutrient doses according to STCR based fertilizer recommendation resulted in higher seed cotton yield and it was at par with 10 t FYM/ha + RDF. Similar results were also reported by Singh *et al* (2007) in American cotton.

It is pertinent to mention that the doses of fertilizer nutrients were reduced on an average by 20 kg N and 12 kg $P_2O_5$ /ha in treatments TY-30 FYM and TY-35 FYM, where 15 t FYM/ha was also applied, in comparison to TY-30 and TY-35 treatments, respectively in irrigated conditions. In general, the yields under STCR-IPNS were higher than STCR fertilizer alone which might be due to favourable environment in rhizosphere of the crop due to improvement in soil conditions. Antil and Narwal (2007) indicated that FYM is the store house of nutrients supplying micro and secondary nutrients in addition to major nutrients and its continous application resulted in sustainable crop productivity and improvement in soil health. The pooled data of the two years revealed that the highest mean grain yield of pearl millet was recorded in TY 35 FYM treatment which decreased in the following order: TY 35 FYM> TY 35 > TY30 FYM > TY30 > PR > > FP > control under irrigated conditions of Hisar district, Haryana.

**Response yardstick**

The pooled mean response yardstick under irrigated condition varied widely from 4.53 in PR to 6.45 kg/kg in TY-30 FYM treatment. The mean response yardstick on the basis of two years pooled data was 4.70, 4.53, 6.41, 6.35, 6.45 and 6.41 kg of seed under irrigated condition per kg of applied nutrients under irrigated condition. These high response yardstick values in different treatments revealed the high responsiveness of pearl millet crop to nutrient application. The response yardstick was the highest in targeted yield treatment of TY-30 FYM (mean 6.45), followed by TY-35 FYM and TY 30 (mean 6.41) and TY-35 (mean 6.35). The higher response yardstick under STCR approach over PR and FP might be due to balanced supply of nutrients from soils as well as fertilizers and manures. The relatively higher response ratio at yield target of 30 q/ha than at 35 q/ha might be due to better nutrient use efficiency at low yield target levels. Rao and Srivastava (2000) reported that the balanced supply of nutrients under STCR-IPNS, efficient utilization of applied fertilizer nutrients in the presence of organic sources and synergistic effect of the conjoint use of various sources of nutrients resulted in higher responsivness of crops to nutrient application

**Per cent achievement of yield targets**

The pooled data presented in table 3 indicated that the yield targets of 30 and 35 q/ha of pearl millet were fully to marginally achieve at different locations in both the years under irrigated conditions. The yield targets of 30 and 35 q/ha with fertilizers alone (TY-30 and TY-35) was achieved within deviations of -5.0 to +2.1 and -5.3 to +0.7 per cent, respectively. Similarly, 30 and 35 q/ha yield targets under IPNS (TY-30 FYM and TY-35 FYM) were achieved within deviations of -3.7 to + 3.2 and -3.6 to + 0.6 per cent, respectively. These results clearly revealed the validity of soil test based fertilizer prescriptions for targeted yields of pearl millet under STCR/STCR-IPNS as all the targets were achieved within acceptable limit of ± 10 per cent (Saranya *et al.*, 2012). Goyal and Singh (2018) also validated the targeted yield equations for cotton under STCR and STCR IPNS and found the variation in yield within the ± 10 per cent.

**ECONOMICS**

The economics of fertilizer and FYM applied and resultant yield of crop was worked out for each treatment and field for both the years by considering the prices of nutrients and produce prevailing in respective years (Table 3). There was a wide variation in the benefit from additional yield (response) in different treatments and locations. The mean benefit pooled for different locations for two years was Rs. 13510/-, 17951/-, 20139/-, 28992/-, 21337/- and 29956/- per hectare in FP, PR, TY 30, TY 35, TY 30 FYM and TY 35 FYM treatment, respectively. Thus, the net profit after subtracting the cost of fertilizers and FYM from the total benefit was also highest in TY 35 FYM (Rs. 24443/-) which was followed by TY-35 (Rs. 23898/-), TY 30 FYM (Rs. 17150/-), TY 30 (Rs. 16577/-), PR (Rs. 13683/-) and lowest profit

of Rs. 10209/- per hectare in FP treatment under irrigated condition. The higher profit in yield target of 35 q/ha was due to higher yield obtained in the treatment. The B:C varied from 4.12 to 6.12 in different locations and years under irrigated conditions. The mean B:C of two years for different locations varied from 4.21 in PR treatments to 6.12 Rs/Re invested on nutrients in PR treatments. The B:C under different treatments are viable and remunerative. The farmers, therefore, should go for STCR-IPNS approach for 35 q/ha yield target owing to higher productivity, benefit from additional produce, total profit and higher marginal B:C. The net profit in TY 35 / TY 35 FYM was Rs 24443/- and Rs 23898/- as compared to Rs. 10209 /ha in FP treatment with higher productivity of about 1665 to 1614 kg/ha in former treatments. The farmers' may opt for STCR approach for lower yield targets of 30 q/ha under resource constraints. These results clearly revealed the superiority of STCR based fertilizer recommendations over farmers' practices and general package recommendations. Sharma *et al*. (2015), Sharma *et al*., 2023, Rani *et al*., 2022, Singh (2017) and Milap-chand *et al.* (2006) also observed the superiority of STCR based integrated fertilizer recommendations in terms of getting max returns and higher B:C over control in pearl millet-wheat and mustard-wheat cropping system.

## CONCLUSION

Soil test crop response based fertilizer prescription equations under IPNS for pearl millet under irrigated conditions developed at Research Farm were found to hold good at farmers' field conditions. The results of present study clearly demonstrated that balanced nutrients application only through fertilizers (PR) without knowledge of soil fertility is undermined by the actual balance nutrients application to bridge the gap between the total crop requirement of nutrients and those supplied by the soil. The STCR approach serve this purpose recommending site specific nutrient application considering the crop requirement and replenishment of nutrients from soil. The targeted yield based fertilizer recommendations are dynamic in nature as it can be increased or decreased for each unit decrease or increase in soil available nutrients. The fertilizer nutrients application for 35 q/ha grain yield target of pearl millet based on soil test under irrigated condition was found to be superior over farmers' practice (FP) and generalized package recommendations owing to higher response, response yardstick, productivity, benefit and viable marginal B:C.

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