AGRONOMY ANNUAL PROGRESS REPORT: 2022-23

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A. Multi-location trials

Agronomic investigations on different small millets *i.e*., finger millet, foxtail millet, prosomillet,little millet,kodo millet barnyard millet and browntop millet were carried out at Almora, Athiyandal, Bengaluru, Dindori, Dholi,Hagari, Jagdalpur, Kolhapur, Mandya, Nandyal, Peddapuram,Ranchi (Kanke), Ranichauri, Rewa, Vizianagaram and Waghai centres and the results obtained during cropping season of 2022-23 are presented in brief.

2.1: Evaluation of pre-released genotypes to fertility levels

At Almora, Athiyandal, Bengaluru, Dindori, Dholi, Hagari, Jagdalpur, Kolhapur, Mandya, Peddapuram, Ranchi (Kanke), Ranichauri, Rewa, Vizianagaram and Waghai, field experiments were conducted to evaluate the response of pre-released genotypes of small millets to different fertility levels. Results shown that the grain yield and economics of genotypes varied with locations and fertility levels (Table 2.1.1 to 2.1.6).

2.1.1. Finger millet

The experiments on pre-released finger millet varieties to different levels of nutrients under rainfed condition were conducted at South (Mandya, Peddapuram, Vizianagaram and Waghai) and North zones (Almora, Dindori, Ranchi, and Ranichauri) during 2022-23.

South zone

Fertility levels: Fertility levels showed significant response for growth and yield parameters. Plant parameters differed significantly among different fertility levels and a fertility gradient of 125% recorded significantly higher plant height however these values were found at par with the fertility level of 100%. Whereas, the yield attributes (productive tillers and 1000 seed weight) and grain yield showed significant variation among different fertility levels and significant values were observed at 125% but were immediately followed by 100 and 75% fertility levels. The grain yield (2761 kg/ha) at 125% was found significantly higher but was found on par with 100 and 75% RDF. Whereas, straw yield at F3(5403 kg/ha) was found significant and was followed by 100% RDF. The gross returns (Rs.91196/ha), net returns (Rs.41072/ha) and B:C (2.72) also followed the similar trend of grain yield. The nutrient uptake observations indicated that at 125% RDF for nitrogen uptake and at both 125 and 100% RDF for phosphorous and potassium uptake, crop exhibited very good response and observed with significantly higher values compared to other fertility levels.

Performance of varieties: There was a significant response for plant growth and yield parameters among varieties. Among finger millet varieties, National check PR 202 has recorded significantly taller plants compared to rest of the varieties and tested variety FMV 1194. However, the tested variety had more productive tillers and was found significantly higher than national check VL376 but was found at par with other national checks GPU 67 and PR 202. With regard to days to 50% flowering and maturity, the national check PR 202 taken significantly longer days to attain 50% flowering and maturity followed by the tested variety. GPU 67 again recorded significantly higher grain yield compared to other national check but was found on par with the tested entry FMV 1194 while, the significant higher values of harvest index was found at tested entry. Even from the economics (gross return, net return and B:C ratio) point of view, the national check GPU 67 again proved to be promising followed by the tested entry FMV 1194. In addition, these two varieties again showed good response for nutrient uptake by crop for nitrogen, phosphorus and potassium.

A non-significant response was noticed for interaction between pre-released varieties and fertility levels.

North Zone:

Fertility levels: Mean over the locations data indicated that application of different levels of fertility showed significant difference for growth, yield and economic parameters. The significantly taller plants were seen at 125% RDF as compared to the absolute control and 75% RDF however, the plants observed at 125% and

100%RDF were found statistically on par. The productive tillers and 1000 seed weight also followed the same trend.
The plants at different levels of fertility levels didn't show significant response for days to maturity however in absolute control, plants attained earlier for days to 50% flowering compared to the rest. The fertility levels showed significant response and significantly higher values for 1000 seed weight, grain yield and straw yield. However, these parameters at 125, 100 and 75 per cent application of RDF fertility levels were found on par with each other. In addition, the economic analysis results at 125% RDF based on the mean over location, further supported by accounting with higher gross, net return and B:C ratio. The nitrogen uptake by the crop at 125 has showed the significant response as compared to other fertility levels while, phosphorous and potassium uptakes showed on par values among different levels when statistically analysed.

Performance of Varieties: Varieties showed significant response for growth, yield parameters, yield, economic indices. The national check PR 202 was observed with significantly taller plants compare to other national check sand tested varieties except FMV 1198 however, VL 376, PR 202, FMV 1198 and FMV 1191 were found with significant number of productive tillers and GPU 67 has taken little longer days to reach 50% flowering and maturity as compared to other varieties. But for 1000 seed weight, none of the varieties showed significant difference in values. For grain yield, the tested variety FMV 1191 surpassed significantly over national check GPU 67 however, was found on par with other national checksVL376 and PR202 and with other tested varieties i.e., FMV 1194 and FMV 1198. For straw yield, varieties did not exhibit significant difference but the harvest index was significantly higher with FMV1191 followed by FMV 1194 and VL 376. Subsequently, the economic parameters further substantiated the good performance of tested entry FMV 11191 followed by FMV1194 and FMV 1198 than national checks. The nutrient uptake by varieties at Almora did not differ significantly for phosphorous and potassium except nitrogen wherein, the tested entry FMV 1191 was observed with significantly higher uptake over others.

The interactions of fertility levels and varieties showed non-significant response for all parameters.

2.1.2 Foxtail millet

To find out the response of pre-released foxtail millet varieties to different levels of fertility under rainfed conditions, an experiment was carried out at Hagari, Kolhapur, Mandya and Nandyal during 2022.

Fertility levels: Significant responses were noticed on growth and yield of crop at different fertility levels. A significantly higher grain yield (1780 kg/ha) was found at 100% RDF fertility level followed by 125% (1771 kg/ha) and 75% RDF (1403 kg/ha) however, these three fertility levels were observed to statistically on par with each other. Whereas, significantly the lowest grain yield was noticed at absolute control (1007 kg/ha).Whereas, the significantly higher straw yield was recorded at 100 % RDF but was found statistically similar with 125% RDF. The better performance of crop at higher fertility levels were supported by higher expression of growth and yield parameters like plant height, no. of productive tillers, dry matter accumulation, 1000 seed weight etc. Further, the fertility level of 100%RDF was resulted with higher returns and benefit cost ratio when compared to either higher or lower fertility levels.

Performance of varieties: Anon-significant difference in all India mean grain yield of pre-released varieties of foxtail millet was noticed. The significantly higher values of plant height, productive tillers and 1000 seed weight was observed with V3 i.e., national check SiA3156 further, all these eventually resulted in harvesting significantly higher yield (grain & straw yield) which was found significantly superior over tested variety FXV 645 but was on par with DhFT 109-3. Economics i.e. gross return, net return and Benefit cost ratio were also followed the similar trend. The nutrient uptakes also showed the similar kind of response among varieties tested. No significant response was noticed for interactions of fertility levels and varieties.

2.1.3 Proso millet

The experiment on knowing the response of pre-released proso millet varieties to different levels of fertility under rainfed condition was conducted at Athiyandal, Dholi and Vizianagaram during 2022-23.

Fertility levels: There was a non-significant difference noticed among different fertility levels for days to 50% flowering, maturity, 1000 seeds weight and harvest index. Crop at higher fertility level of 125% RDF has out yielded all other fertility levels and established its supremacy however, the straw yields at 75 to 125% RDF were statistically on par yields. The 100% RDF also found economically feasible and hence, growing proso millet at 100% RDF or lower fertility level of 75% RDF is profitable as crop found highly responsive at 100% fertility gradients. Again, the nutrient uptakes also found with significantly higher values at 100% RDF as compared to 125 and 75% RDF.

Performance of varieties: On all India mean basis, prosomillet pre-release genotypes did differ significantly in respect to productive tillers, grain yield, harvest index and nutrient uptakes. National check TNAU 164 was found with significantly taller plants than pre-released variety PMV 466. The tested entry was found with significantly shorter days to attain 50% flowering and maturity however, the national check TNPm 230 has taken the longest day of 73 days for maturity. The grain yield did not differ statistically among varieties however for straw yield, the national check TNPm 230 has out yielded all varieties except other national check TNAU 164. The higher performance of the varieties for straw yield was supported by the best exhibit of growth parameters and even economics (Gross return, net return, cost of cultivation and B:C ratio) also indicated the superior performance of national check (TNPM 230) over tested variety. There was non-significant difference noticed for interactions of fertility levels and pre-released varieties.

2.1.5. Barnyard millet

A trial was conducted at Almora, Bengaluru,Jagdalpur and Ranichauri during 2022 to know the response of pre-released barnyard millet varieties to different fertility levels under rainfed conditions (Table 2.1.5).

Fertility levels: The fertility levels showed significant differences on barnyard millet growth and yield parameters. The per cent increase in grain yield of 77.4, 29.2 and 6.5 per cent were noticed at 125, 100 and 75 per cent recommended dose of fertilizers, respectively over absolute control. However, the fertility levels of 125 and 100 per cent were found on par with each other and economic parameter (B:C ratio) also signifying the fact that 100 %RDF is economically sufficient to harvest higher yield in little millet. Straw yield also followed the trend of grain yield. Again, parameters like productive tillers, 1000 seed weight, straw yield, harvest index, gross return, net return and potassium uptake by crop found to be higher at higher fertility level and started declining towards lower levels of fertility however, values in most of these parameters were found statistically on par between 125 and 100% fertility level. The nitrogen, phosphorous and potassium uptakes were also found with higher values at 100 % and 125% RDF as compared to other fertility levels.

Performance of varieties: The national check VL 207 recorded significantly higher values for plant height, productive tillers, seed weight and grain yield followed by tested entry BMV 611. However, BMV 611 has failed to exert marked influence over straw yield over national check VL 207 but was found on par with other national check DHBM 93. The economic parameters i.e., gross return, net return and B:C and nutrient uptakes also ascertained the fact of higher performance of the national check and pre-released genotype.

The interactions of fertility levels and varieties showed non-significant response for all parameters.

2.1.6. Kodo millet

During 2022, under different fertility levels, pre-released kodo millet varieties were tested at Athiyandal, Jagdalpurand Rewa under rainfed conditions and the result is presented in Table 2.1.6.

Fertility levels: A significant difference was noticed among different fertility levels. 125% RDF has documented significantly more 1000 seed weight (4.68g) immediately followed by 100 and 75% RDF which resulted in producing significantly higher grain yield (3157 kg/ha) and straw yield (4971kg/ha) however, these were found on par with values obtained at 100 and 75%RDF. Significantly the lowest grain (1903 kg/ha) and straw yield (2882 kg/ha) was obtained at absolute control. Further, higher gross return and net returns were noticed at 125% RDF followed by 100%RDF yet, the highest benefit cost ratio was documented at 100% RDF. The nutrient uptake was found significantly higher at 125% RDF as compared to absolute control but was found at par with al other fertility levels of 100 and 75 % RDF.

Performance of varieties: On all India mean basis, a grain yield of 2916 kg/ha was obtained with the tested entry KMV 568 which was found to be significantly higher over national check RK 390-25 but was found on par with other check varieties CKMV 1 and TNAU 86. Whereas, the significantly higher straw yield (4477 kg/ha) was obtained at check CKMV 1 over test entry KMV 68 and national check TNAU 86.There was a non-significant difference noticed for 1000 seed weight, harvest index and nutrient (nitrogen & potassium) uptakes by crop. Economic parameters i.e., gross return, net return and benefit cost ratio also have shown that tested entry KMV 568 had higher returns and benefit cost ratio than other varieties.

The interactions between fertility levels and pre-released varieties of kodo millet showed a non-significant response for all parameters.

2.2: Nutrient management in small millets

2.2.1. Response of small millets to liquid biofertilizers and their mode of application

In response to lower the cost of production and to cut down the cost on inorganic nutrients and also to know the response of liquid consortia or liquid biofertilizer in small millets, a study was conducted in small millets to know their response for liquid biofertilizers and their effects on crop growth, yield attributes, grain yield, straw yield, economics, nutrient uptake, nutrients availability in soil and soil microbial dynamics. The liquid biofertilizer contains *Azospirillumlipoferum* (nitrogen fixer), *Bacillus megaterium* (Phosphorous solubilising bacteria) and *Frateuria aurantia* (potassium solubilising bacteria).

Foxtail millet: The liquid biofertilizer trial on foxtail millet was conducted at Bengaluru, Dholi and Nandyal during *kharif* 2022(Table 2.2.1.B). Significantly higher number of productive tillers and numerically higher values of all the growth and yield parameters were observed at T1, T4 and T3 which all cumulated in resulting substantially higher and significant grain and straw yield at T1 and the next best treatments were found to be at T4 and T3 followed by T6and T2. The analysis of economic parameters i.e., gross return, net return and B:C ratio also have further indicated that treatments from 100 to 85% RDF along with addition of liquid biofertilizer have enhanced the grain yield of crop compared to 100% only through RDF (T10) and resulted the fact that upto 15-30% saving in RDF could be possible by going for liquid biofertilizer substitution without sacrificing the yield of crop. Further nutrient uptake by crop also was enhanced when crop was supplemented with liquid biofertilizer and there was slight increase in the availability of nutrients in soil when compared to T10, 70%RDF along with liquid biofertilizer substitution and absolute control. With respect to the incidence of pest and disease incidence among different treatments, crop was having slightly lesser incidence of blast, downy mildew and the attack by helminthosporium at 100, 85 and 70% RDF and liquid biofertilizer substitution treatments though not found with significant difference.

The pooled data of two years (2020, 2021 & 2022) over locations also followed the similar trend and concluded that that liquid biofertilizer provided at T1 followed by T3 and T4 as most beneficial and cost-effective measure for reducing the cost of production and sustained productivity (Table 2.2.1.B).

Proso millet: The experiment on liquid biofertilizer and its substitution with RDF was conducted at Mandya and Ranchi during *kharif* 2022 and the data is presented in Table 2.2.1.C. The significantly higher grain yields were

obtained with T1 however was found on par with T4, T3 and T10but were significantly superior over 70% RDF with liquid biofertilizer substitutions and absolute control. However, though non-significant values were obtained for growth and yield attributes but higher were noticed at T1 followed by other treatments which have liquid biofertilizer substitution and treatment with recommended dose of fertilizer(T10). Similarly, T1, T4 and T3 further accounted with higher net returns and Benefit cost ratios confirming the advantage for usage of liquid biofertilizers for higher productivity in Proso millet and also for reducing the cost of production.

The pooled data of two years (2020, 2021 & 2022) over locations also followed the similar trend and concluded that that liquid biofertilizer provided at T1 followed by T3 and T4 as most beneficial compared to recommended package of nutrients(T10) and cost-effective measure for reducing the cost of production and sustained productivity (Table 2.2.1.C).

Little millet: The trial was conducted at Jagdalpur, Mandya and Vizianagaram during *kharif* 2022 and the data on growth, yield, economics and ancillary parameters are presented in Table 2.2.1.D.

Treatment 1 which is provided with 100%RDF + seed treatment + soil application with liquid biofertilizer found with significantly higher grain yield (1117 kg/ha) which has surpassed all treatments except T3 and T4 while, straw yield (3269 kg/ha) was significantly superior over rest of treatments but was found at par with T3, T4, T2 and T6. Whereas, the treatment 11(absolute control) which was not supplied with any external nutrient or biofertilizer showed significantly the lowest grain and straw yield as compared to all treatments imposed. The treatments which had 85% RDF and supplementation with liquid biofertilizer either through soil application or seed treatment or from both also have performed equally good for growth, yield attributes and further validated by obtaining higher nutrient uptakes, higher net return and B:C ratio. Though T1 was emerged as the best treatment from the fact of yield and returns however, recommending T3 or T4 to farmers would be beneficial from economic and practical point of view. The nutrient availability in soil also found higher with T1 followed by T2 and T3. The pest and disease incidence did not show much variation among different treatments imposed in the experiment.

The pooled data of two years (2020, 2021 & 2022) over locations also followed the similar trend and concluded that that liquid biofertilizer provided at T1 followed by T3 and T4 as most beneficial and cost-effective measure for reducing the cost of production and sustained productivity (Table 2.2.1.D).

Kodo millet: At Athiyandal, Dindori and Ranchi, the trial on Kodo millet was conducted and the results are presented in Table 2.2.1.E. Significantly higher productive tillers per plant, higher dry matter accumulation per plant, grain yield and nutrient uptakes were differed significantly among different treatments wherein, T1 was found with significantly higher values over other treatments but was comparable with T3, T2, T4 and T10. However, other parameters did not differ significantly among treatments. The significantly higher grain yield of 2175 kg/ha was harvested with T1 however, it was closely followed by T2, T5, T6 and other treatments except T9 and T11. Interestingly, straw yield did not differ statistically. The economic indices also registered the fact that liquid biofertilizers have an important role to play in kodo millet for sustainable productivity and treatment 1 was found most profitable and feasible technology. The nutrient uptake by the crop and nutrient availability in soil after the harvest further established the beneficial effect of T1 in sustaining the productivity of crop and soil as well.

The pooled data of two years (2020, 2021 & 2022) over locations also followed the similar trend and concluded that that liquid biofertilizer provided at T1 followed by T3 and T4 as most beneficial compared to recommended package of nutrients(T10) and cost-effective measure for reducing the cost of production and sustained productivity (Table 2.2.1.E).

Barnyard millet:The trial of liquid biofertilizer on Barnyard millet was conducted at Jagdalpur, Mandya and Ranichauri during *kharif* 2022 and the result is presented in Table 2.2.1. F.

Among different treatments, significantly higher plant height was recorded with T1 followed by T3, T2, T10 and T4. The treatment T1 produced more number of tillers and found with significantly higher values of dry matter

accumulation (DMA) at 30 and 60 DAS but was found at par with all treatments except treatments T8 and T11. Yet again, these treatments have taken little longer days to attain 50% flowering and maturity as compared to other substitution levels. All these favour able growth and yield attributes have finally resulted in significantly higher grain and straw yield at T1 as compared to T5, T7, T8, T9 and T11. The higher response of the crop at these treatments was further verified by having obtained higher economic returns. The results once again proved that when crop is supplied with 100 or 85%RDF with liquid biofertilizer through soil and seed treatment was found economically feasible for enhancing the crop productivity. Further, crop at these treatments were relatively less infected with pest and diseases specially blast incidence as compared to T10 (Recommended dose of fertilizer) and T11(Absolute control).

The pooled data of two years (2020, 2021 & 2022) over locations also followed the similar trend and concluded that that liquid biofertilizer provided at T1 followed by T3 and T4 as most beneficial compared to recommended package of nutrients(T10) and cost-effective measure for reducing the cost of production and sustained productivity (Table 2.2.1.F).

Browntop millet: The experiment on Browntop millet response for liquid biofertilizer was conducted at Athiyandal and Bengaluru (Table 2.2.1.G). The treatment T1(100% RDF + seed treatment + soil application) registered significantly higher grain yield and was found on par with treatments where liquid biofertilizer was used for soil application or seed treatment or both along with 100 and 85%RDF except T9 and T11. The higher values of growth and yield parameters at T1, T3 and T4 had favourable effect in producing higher yield. The straw yield also showed similar response as grain yield at T1 was found significantly higher than other treatments however shown on par results with T3, T4 and T2. Finally, the higher net returns and B:C ratios were again registered with T1, T4 and T2 signifying the importance of liquid biofertilizer usage in browntop millet for higher productivity and economics.

The pooled data of two years (2020, 2021 & 2022) over locations also followed the similar trend and concluded that that liquid biofertilizer provided at T1 followed by T3 and T4 as most beneficial and cost-effective measure for reducing the cost of production and sustained productivity (Table 2.2.1.G).

2.2.2. Response of Finger millet to non-chemical (organic) farming under rainfed and irrigated situation

To investigate the effect of non-chemical farming in small millets under rainfed situation, an experiment was conducted at Atthiyandal, Bengaluru, Dholi, Dindori, Mandya, Nandyal, Ranichauri and Waghai, during *Kharif*2022 under rainfed situation. The data on growth, yield, economics, nutrient uptake and nutrient availability in soil are presented in Table 2.2.2.

Finger millet: The trial was initiated during *kharif*2022 atAtthiyandal, Bengaluru, Dholi, Dindori, Mandya, Nandyal, Ranichauri and Waghai. Significant difference in plant height, number of productive tillers per hill, dry matter accumulation at different stages of crop, 1000 seed weight, grain yield, straw yield, economics, nutrient uptake and nutrient availability in soil were noticed among different treatments. Treatment T10(Recommended package) produced significantly higher grain yield (2454 kg/ha) compared to other treatments and the next best treatments based on one-year response, T5, T4 and T2. The straw yield also exhibited similar response wherein, again T10 was found with significantly higher straw yield (5599 kg/ha) however, was found at par with T5 and T2. Whereas, significantly the lowest grain and straw yields were obtained with T1 followed by T9 and T8.The economic parameters when analysed also proved that treatments T10 followed by T7, T8, T5 and T6 exhibited as the most feasible ones and the significant response of crop at these treatments was due to better expression of growth and yield parameters i.e., plant height, number of productive tillers and dry matter production at different growth stages. The good response of crop at recommended package was also supported with higher nutrient uptakes and further higher availability of nutrients in soil. Again, based on results over locations, T10 imposition because

of timely control of weeds and needy plant protection measures, resulted in lesser weed density, lower disease incidence and all these contributed to T10 in emerging as the best treatment based on one year experimentation.

Kodo millet: The results indicated the response of crop to different treatments at Dindori during *kharif* 2022. Among different treatments, significantly taller plants, more number of productive tillers, higher dry matter accumulation, longer days to attain 50% flowering and maturity, 1000 seed weight, grain yield, straw yield, harvest index, nutrient uptakes, higher nitrogen and phosphorous availability in soil, lesser weed density and lower pest and disease incidences were noticed with treatment T2 followed by T10, T5, T9 and T8. However, based on the economic analysis the treatment T10 was found best followed by T8 (bio fertilizers use) and T9.

2.2.3. Nano fertilizers for sustainable millet production under different systems of establishment in Small millets

The experiments were initiated at different locations during *kharif* 2021and 2022to investigate the effect of nanofertilizer in Small millets. The data on growth, yield, economics, nutrient uptake and nutrient availability in soil are presented in Table 2.2.3.

2.2.3.1 Nano fertilizer use in Finger millet

An experiment was carried out at Bengaluru, Karaikal, Ranichauri and Vizianagaram during *Kharif* 2021 and 2022 to know the impact of nano fertilizer in finger millet. Nano fertilizer was tested with two methods of establishment i.e., transplanting and drill method of sowing with different modes of application i.e., seed treatment, root dipping and foliar spray at different stages of crop and reducing the recommended dose of nitrogen (RDN)up to 50% RDN with different combinations of application modes. The nano fertilizer has exerted significant influence for leaf area, dry matter accumulation, protein analysis, nutrient uptake and nutrient use efficiency. However, nano fertilizer combinations failed to have significant impact on plant height, productive tillers, panicle length, panicle weight, 1000 seed weight, grain yield, straw yield, harvest index and on soil properties like pH, EC and OC. Among treatments imposed, T1(Transplanting with recommended practices) and T10(transplanting with 75% RDN + foliar spray of nano nitrogenat 25-30 and 45-50 days after transplanting)have showed the numerically higher values in grain and straw yield and further T7 and T10 were found with significantly higher values with respect to nutrient use efficiency and nutrient uptakes by the crop. Overall, the crop supplied with nano fertilizer through foliar spray at 75% and 50% RDN has shown good response.

2.2.3.2 Nano fertilizer use in foxtail millet

The trial was conducted at Dholi, Mandya, Nandyal and Ranchi during *Kharif* 2021 and 2022 to know the impact of nano fertilizer in foxtail millet. The results indicated that the crop has responded for nano nitrogen fertilizer on mean location basis. Significantly higher plant height, productive tillers, leaf area, dry matter accumulation, panicle length, panicle weight, total no. of grains and filled grains per panicle, 1000 seed weight, grain yield, straw yield, nutrient uptakes, nutrient availability in soil, nutrient use efficiencies etc. were obtained when nano nitrogen was applied to crop through seed treatment and foliar application at different stages of crop. The higher values of these were observed with T12(sowing with 75%RDN+seed treatment + foliar spray at active tillering stage and 7-10 days before flowering) followed by T11(sowing with 75%RDN+foliar spray at active tillering stage + foliar spray at active tillering stage and 7-10 days before flowering), T10(Sowing with 75% RDF + Folia spray at 7-10 days before flowering),T9(sowing with 75%RDN+foliar spray at active tillering stage), and T1(sowing with recommended practice).The straw yield also followed the similar trend signifying the better impact of nan fertilizer on foxtail millet for higher productivity. The results obtained were further supported with having obtained higher net returns and benefit cost ratio at T12 followed by T11 and T1. The nutrient uptake by crop also showed the significant trend of higher values with these treatments along with higher nutrient use efficiencies.

2.2.3.3 Nano fertilizer use in little millet

The results at Jagdalur, Kolhapur and Waghai indicated the response of crop to different modes of application of nano nitrogen fertilizer in little millet. The results indicated that the response of crop to different modes of application of nano nitrogen fertilizer was observed in little millet. The yield data showed significant difference for nano fertilizer use and numerically higher values of plant height, leaf area, number of productive tillers and dry matter accumulation was found with T11(sowing with 75%RDN+seed treatment + foliar spray at active tillering stage and 7-10 days before flowering) followed by T10, T9 and T12. The significantly higher grain yield (1347 kg/ha) was obtained at T11 compared to T2, T3, T4, T5, T7, T6 and T1. Whereas, T10 accounted with significantly higher straw yield as compared other treatments but was found on par with T11, T12 and T1. These treatment (T11, T10, T10 and T12 again emerged as economically feasible as they were found with higher net returns and benefit cost ratio as compared to rest of the treatments.

2.2.4. Effect of foliar application of water soluble fertilizer (WSF) on growth, yield and nutrient uptake of small millets

The experiments on knowing the response of water soluble fertilizer in small millets were conducted at Athiyandal, Bengaluru, Dindori, Jagdalpur, Kolhapur, Mandya, Nandyal, Ranchi, Vizianagaram and Waghaiduring *kharif* 2021 and 2022 and the data on growth, yield, economics, nutrient uptake and nutrient availability in soil are presented in Table 2.2.4.

2.2.4.1 Finger millet

The trial on finger millet was conducted at Bangalore, Mandya, Ranchi and Vizianagaram during *kharif* 2021 and 2022 and the significant response among treatments were noticed. The significantly higher grain yield of3091 kg/ha was obtained at T8(75%RDF+2.0% 19-19-19 at panicle initiation, flowering and grain development stage), which was found with 23.20%, 98.40% and 122.3% higher grain yield than at T2(100%RDF as soil application), T13(Water spray at panicle initiation, flowering and grain development stage) and T1(Absolute control), respectively. Whereas for straw yield, treatments also exerted marked influence and again T8 produced significantly higher yield than other treatments except T12 and T1.The economic parameters also followed the similar trend and a higher value of gross return (Rs.102687/ha, net return (Rs.65713/ha) and B:C ratio (2.81) was seen towards T8 followed by T7. The plant height, nutrient content in plants, nutrient uptake i.e., nitrogen and phosphorus by crops also exhibited significantly higher values at T8 followed by T7 and T2 compared to other treatments however, significantly higher values of nutrients in soil were observed with treatments T3, T4 and T3 at Mandya centre. The nutrient use efficiency also found higher with T8 followed by T7 at Vizianagaram centre.

2.2.4.2 Little millet

At Kolhapur, Nandyal and Waghai, the trial was conducted for 2021 and 2022 and the data on growth, yield and economics is presented in Table 2.2.4.2. The treatments showed significant differences on little millet growth and yield parameters. The plant height was showed significant difference and higher values were observed with T2(100%RDF as soil application) as compared to T1(Absolute control), T13(Water spray at panicle initiation, flowering and grain development stage) and T4(50%RDF as soil application) and T5(50%RDF+1.5%19-19-19 at panicle initiation, flowering and grain development stage). However, significantly higher the leaf area, 1000 seed weight and other parameters have resulted in significantly higher yield(grain & straw) in T2, T12, T11, T8and T7. Further, the economic indices also supported the result by having obtained higher economic returns.

2.2.4.3 Kodo millet

The trial was conducted Athiyandal, Dindori and Jagdalpur during *Kharif* 2021 and 2022 (Table 2.2.4.3). A significant difference was noticed among different treatments for crop responses and T2 has documented

significantly higher plant height (70.24 cm), leaf area (56.93 cm^2), 1000 seed weight (4.25 g) and numerically higher values of other growth and yield attributes all resulted cumulatively in producing significantly higher grain yield (2433 kg/ha) at T2 followed by T8(2384 kg/ha) and T7(2318 kg/ha) whereas, the lowest grain yield was attained at T1(1158 kg/ha) as compared to other treatments. However, the nutrient uptakes and nutrient use efficiencies at these treatments T2, T8, T7, T12, T11 were also found statistically on par and further, these were accounted with higher net returns and benefit cost ratio as compared to other treatments.

2.2.5Screening of Finger millet cultivars for Nitrogen use efficiency

An experiment was initiated at Athiyandal, Bengaluru, Dholi, Hagari and Kolhapur during 2022 to find out the response of finger millet and kodo millet to nutrient use efficiency and to optimise its requirement for sustained productivity. The data on growth, yield, economics and other ancillary data 2022 are presented in Table 2.2.5.

Nitrogen levels: Nitrogen levels showed significant response for plant height, tillers, panicle length, panicle weight, filled grain numbers, 1000 seed weight, grain yield, straw yield, nutrient content in grain, straw and uptake and nitrogen use efficiency and the significantly higher values of all these parameters were recorded with N3(100% RDN) as compared to N2(50% RDN) and N1(No nitrogen). The yield at N3 was accounted with 55.5 higher grain and 51.0 per cent higher straw yield than N0 while, 22.9 higher straw and 18.4 per cent higher straw yield than N1, respectively. Again, N3 was found with significantly higher nitrogen content in grain and straw, nitrogen uptake as well as nitrogen use efficiency than N2 and N1.

Varieties: Varieties did have effect significantly for growth and yield attributes. Variety 4 has significantly taller plants than other varieties except V3. Similarly, V4 had more productive tillers as compared to V2 and V3 but was immediately followed by V5 and V1. However, panicle numbers per m^2 area, panicle length, panicle weight, 1000 seed weight, straw yield, harvest index, N content in grain, N uptake were not differed significantly among varieties. The grain yield obtained at V5(1976 kg/ha) was found significantly higher over V2(1796 kg/ha), V3(1765 kg/ha) and V4(1778 kg/ha) but was found on par with V1(1871 kg/ha). While, the straw yield was not differed significantly among varieties. Further, the nutrient content in grains, straw and nutrient uptake by crop and nitrogen use efficiency was unaltered significantly among varieties.

2.3: Weed management for small millets

A study on herbicides in different concentrations combined with one inter-cultivation was implemented during *kharif* 2021 and 2022 for finger millet and little millet at different locations and the data on growth, yield, weed parameters and economics of study are presented in Table 2.3.1 and 2.3.2.

2.3.1. Chemical weed control studies in Finger millet

Mean over locations (Bengaluru, Dholi, Ranichauri and Vizianagaram) data indicated that significantly higher grain yield of finger millet was obtained with standard practice of two inter cultivation and one hand weeding(T10) (2132 kg/ha) as compared to other treatments (Table 2.3.1). However, significantly the lowest grain yield was obtained with unweeded check(T11) (580 kg/ha). The straw yield also found with significantly higher value at T10(4582 kg/ha) as compared to other treatments of pre and post emergent weedicides imposed treatments but was found at par with T3 and T5. With all these, again treatment T10 obtained higher net return (Rs.53305/ha) and B:C ratio(3.15) but was immediately followed by T5(Bispyribac sodium (10% EC) @ 12.5 g a.i./ha), T7(Metsulfuron methyl+ Chlorimuron ethyl 20 WP@20 g a.i/ha) and T9(2,4 D sodium salt 80 WP @ 800 g a.i./ha).The higher response for yield and economics at these treatments were yet again sustained by lesser weed density and higher weed control efficiency at different crop growth stages. The weed density was differed significantly but at later stages it was markedly different and the significantly the least value of weed density was with T10 followed by T3, T4 and T7 at 30 days after sowing while, the highest weed density found with the unweeded check. The highest weed control efficiency was found with T10 followed by T3, T4, T7 and T9

however at harvest, T10, T5, T9 and T7 were observed with higher weed control efficiencies. The weed index was significantly higher with unweeded check followed by T8, T6 and T2.

2.3.2. Chemical weed control studies in Little millet

At Dindori and Nandyal, a study on weed management studies with herbicides was conducted during *kharif* 2021 and 2022 involving various herbicide like Isoproturon, Oxadiargyl, Bensulfuronmethyl+Pretilachlor, Bispyribac sodium, Ethoxysufluron, Metsulfuron methyl+ Chlorimuron ethyl, Tembotrione, 2,4 D Sodium salt and these were compared with traditional standard practice and absolute control (unweeded check) in Kodomillet (Table 2.3.2).

The significantly higher grain yield was realised at traditional standard practice (two intercultivation and one hand weeding)(2177 kg/ha) as compared to other treatments but was found on par with the weedicide imposed treatment at T7(metsulfuronmethyl+Chlorimuron ethyl 20WP@20 g a.i./ha)(2000 kg/ha). The standard practice(T10) is a laborious and time-consuming methodology, and the usage of herbicides are still advisable if the farmer wishes to go for integrated weed control measure. The straw yield obtained at traditional practice (3657kg/ha) was found at par with T7(3427 kg/ha), T9(3104 kg/ha), T3(3011 kg/ha) and T4(2918 kg/ha). The same trend was also noted where the treatment T10, T7 and T3 for the remuneration aspects like net return and benefit cost ratio. These treatments were also witnessed with lesser weed density, higher weed control efficiency and lesser weed index.

2.4: Moisture conservation in small millets

An experiment was initiated at different locations during *Kharif* 2021 and 2022 to investigate the effect of mulching and hydrogel on the productivity of small millets under rainfed conditions. The data on growth, yield, economics and other ancillary parameters are presented in Table 2.4.

2.4.1. Finger millet

An experiment was implemented at Bengaluru, Hagari, Jagdalpur and Karaikal during *kharif* 2021 and 2022 and the data is presented in Table 2.4.1. The significantly higher grain yield and straw yield were obtained with T8(Crop residue mulch @ 5.0 t/ha + hydrogel @ 7.5 kg/ha) (2815 kg/ha and 6389 kg/ha, respectively) as compared to T1, T3 and T4 however was found on par with T7, T6 and T4. The straw yield also showed the similar response at T8 followed by T7 and T6. The water use efficiency calculated was also differed significantly with obtaining higher values at T8 followed by T6 and T7. The analysis of economic indices again indicated that T8 followed by T7 and T6 as feasible practices. The observation on gravimetric soil moisture content and bacteria, fungi, actinomycetes and dehydrogenase activity in the soil also indicated the beneficial impact of mulching and hydrogel and finally on the productivity in finger millet.

2.4.2. Foxtail millet

At Mandya and Nandyal, the trial was carried out during *kharif* 2021 and 2022 to know effect of mulching and hydrogel on the productivity of foxtail millet (Table 2.4.2). The trial at Kolhapur and Ranchi was vitiated however, the trial at other centres conducted successfully wherein, the significant differences in grain yield, straw yield, gravimetric soil moisture content at different schedules of moisture content at 45 and 60 days after sowing and microbial content in soil were observed. Whereas, plant stand in net plot at harvest, plant height, number of productive tillers per hill, 1000 seed weight, water use efficiency, harvest index and gravimetric soil moisture content at 15 days after sowing did not differ significantly. The promising attributes resulted in significantly higher grain yield at T7 which was closely followed by T8 whereas, the lowest grain yield was recorded with T1. The straw yield also followed the similar trend among treatments. Treatment 7 was found with higher net returns and also found as feasible along with numerically higher values of soil moisture and slightly higher microbial count at Nandyal.

2.4.3. Barnyard millet

At Athiyandal, Dholi and Dindori, the trial was conducted during *kharif* 2021 and 2022 to know effect of mulching and hydrogel on the productivity of barnyard millet (Table 2.4.3). Among different treatments imposed,

significantly higher plant height, number of productive tillers, 1000 seed weight, grain yield, straw yield, water use efficiency, and gravimetric moisture content were observed. The promising growth and yield attributes all cumulated to higher grain yield at T7 which was closely followed by T6 and T5. Whereas, the lowest grain yield was recorded with T1(absolute control;1253 kg/ha) followed by T2(crop residue mulch @5.0t/ha;1739 kg/ha)). However, based on economic indices, the treatment T7 was found feasible followed by T6. The soil moisture content at Dindori also proved that inclusion of mulching and hydrogel in the treatment have resulted in more moisture retention at different stages of the crop.

2.5: Millet cropping systems for sustainable productivity

2.5.A. Enhancing the Finger millet – system productivity with inter crops

At Bengaluru, Mandya and Ranichauri, an evaluation for enhancing the millet system productivity of finger millet was implemented during *kharif* 2021 and 2022. The growth parameters, grain yield, straw yield of base crop and intercrop, MGEY and economics are indicated that the plant height of base crop and intercrop at harvest was influenced significantly among sole crops and their association with intercrops. Among different intercrop associations with main crop, the significantly taller plants were observed at sole crop and then followed with T6, T5 and T2. Whereas, among intercrops, the taller plants were niger and between its association with maincrop, no significant difference was noticed.

The grain and straw yield of base crop showed significantly higher yield at sole crop as compared to other associations but was found on par with T6 and T5. The intercrop grain yield was also showed significant difference and among different inter crop tried, the significantly higher grain yield was recorded with ground nut as compared to other intercrops and their associations with base crop. Whereas, millet grain equivalent yield was significantly impacted by different sole crops and their different associations with intercrops. Significantly higher millet grain equivalent yield was obtained with T5(finger millet + ground nut (4:2)) over other associations of finger millet with other intercrops but was found on par with T5(Finger millet and groundnut (6:2)), and all other associations except T3, T7, T8 and sole crop of intercrops. Keeping in view of remuneration realised i.e., gross return and net return, the intercropping of finger millet with groundnut in association of 4:2 or6:2 was found more economically beneficial and the next associations were T9, T1, T2, T4 and T3.

2.5.B. Enhancing the Foxtail millet – system productivity with inter crops

The mean over locations (Bengaluru,Jagdalpur, Kolhapur and Nandyal) during 2021 and 2022 showed that the significantly higher millet grain equivalent yields (2101 kg/ha) was realised with foxtail millet+ ground nut (4:1) followed by foxtail millet with groundnut (6:2) proportions and sole crop of foxtail millet Keeping in view of remuneration realised i.e., gross return, net return and more importantly benefit: cost ratio point of view, the results showed that growing of sole crop foxtail millet and ground nut was a better option. However, if the farmer wishes to adapt a intercropping system, ground nutcan be utilised @ two rows with every six or four rows of foxtail millet so that profitable income can be achieved (Table 2.5.B).

2.6. Performance and economic evaluation of farm machinery in small millets

To know the feasibility of farm machinery for harvesting in finger millet and also to assess the performance of different duration finger millet varieties for different machineries, an experiment was laid out at Bengaluru and Mandya during *Kharif* 2022. The data on growth, yield attributes and economics of the study are presented in Table 2.6.

The significantly higher grain yield was recorded with manual harvesting as compared to harvesting by reaper and combined harvester. Similarly, the straw yield also followed the trend and significantly higher yield was found with manual harvesting than other methods. The net return indicated that treatments i.e.,manual harvesting is comparatively better than reaper harvesting and combined harvester however, benefit cost ratio indicated that

there is not much significant difference among harvesting methods was observed. The lesser and higher harvesting losses during harvesting were recorded with manual harvesting and combined machine harvesting, respectively. Interestingly the labour required for harvesting was found 85 and 70%lesser with combined machine harvesting and reaper harvesting as compared to manual harvesting, respectively. In addition, the combined machine harvesting has recorded very lesser field operation time and high field efficiency. Further, stubble height after harvesting, shattering losses and fuel consumption were found with higher values for combined machine harvesting too.

Among different varieties, plant height, productive tillers per hill, days to maturity, straw yield, lodging, field efficiency, stubble height after harvesting and shattering losses were differed significantly among varieties. V5 has recorded significantly taller plants however, V1 was found with significantly more tillers than other varieties tested along with significantly longer days to attain maturity. Again, straw yield differed significantly among different varieties unlike grain yield wherein, V1 followed by V5 have recorded significantly higher straw yield than other varieties and significantly the lowest straw yield was recorded with V4. From the economic analysis, V1 is more remunerative than other varieties but was followed by V5. However, V4 and V3 were found with lesser susceptible for lodging which is found as a beneficial trait for machine harvesting. The field efficiency in harvesting these varieties by machine harvesting though did not differ significantly among varieties, V2, V3 and V4 were having more field efficiency than V1 and V5 for machine harvesting. Finally, V1 was found with significantly higher values of stubble height after harvesting while, V5 was recorded with more shattering losses.