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A field experiment was conducted during rabi season of 2017-2018 on a mixed black calcareous soil (Typic Ustertep - Periyanaickenpalayam soil series) at Eastern Block, Tamil Nadu Agricultural University, Coimbatore to refine the existing fertilizer prescription equations under Integrated Plant Nutrition System (IPNS) for hybrids to suit pearl millet variety. The experiment comprised of eleven treatments with three replications in Randomized Block Design. The experimental results revealed that there was a progressive increase in response from lower target to higher targets and the magnitude of response was higher under STCR-IPNS than under STCR-NPK alone treatments. Using the experimental data, the basic parameters viz., nutrient requirement (NR), per cent contribution of nutrients from soil (Cs), fertilizers (Cd) and FYM (Cfym) towards total N, P and K uptake by pearl millet (var. CO 10) were computed based on targeted yield model. It was found that pear millet variety requires 2.81, 1.33 and 2.53 kg of N, P2O5 and K2O respectively to produce one quintal of grain. The contribution of nutrients from soil, fertilizers and FYM for N was 26.36, 45.44 and 27.55 per cent; for P2O5, it was 38.51, 44.14 and 16.04 per cent and for K2O it was 10.33, 87.45 and 40.15 per cent respectively. Making use of the refined basic parameters, Fertilizer Prescription Equations (FPEs) were developed under NPK alone and IPNS for pearl millet variety. Ready reckoner of fertilizer doses (nomograms) were formulated for a range of soil test values and for desired yield target viz., 3.0, 3.5 and 4.0 t ha⁻¹. For an average soil test value of 180:24:460 kg ha⁻¹ and yield target of 4.0 t ha⁻¹, 105, 51 and 25 kg of fertilizer N, P2O5 and K2O is to be applied along with FYM @ 12.5 t ha⁻¹. The extent of saving of inorganic fertilizers for pearl millet with the application of FYM @ 12.5 t ha⁻¹ (with 21% moisture, 0.64, 0.27 and 0.46 % N, P and K respectively) was 38, 22 and 25 kg of fertilizer N, P2O5 and K2O respectively.

Key words: STCR-IPNS, Pearl millet, Fertilizer prescription equations.

Pearl millet (Pennisetum glaucum L.) is the world's hardest warm season cereal crop (Reddy et al., 2012) and it is the most widely cultivated cereal in India after rice and wheat and grown annually on 29 million ha in the arid and semi-arid regions of Asia, Africa and Latin America. India is the largest producer of pearl millet in Asia, both in terms of area (7.12 million ha) and production (9.9 million tonnes) with an average productivity of 1272 kg ha⁻¹. India had witnessed a major breakthrough in total production and productivity of pearl millet after the release of high yielding varieties (Yadav, 2016). In Tamil Nadu, pearl millet is cultivated in an area of 0.577 lakh ha with a production of 1.77 lakh tonnes and average productivity of 3077 kg ha⁻¹ during 2015-16 and a blanket recommendation of 80:40:40 and 70:35:35 kg N, P2O5 and K2O ha⁻¹ for hybrids and varieties respectively along with FYM @ 12.5 t ha⁻¹ is being followed for pearl millet in Tamil Nadu.

Fertilizer use in India is relatively low as compared to many other countries and NPK use ratio is highly imbalanced (6.7:2.7:1 in 2016-2017 vs an optimum ratio of 4:2:1) which has led to widespread negative nutrient balance in most Indian soils to the tune of 8-10 mt NPK (Satish Chander, 2014). Therefore, management of nutrients should be given proper attention to maintain or increase yields and sustain productivity. Fertilizer schedules should therefore be based on magnitude of crop response to applied nutrients at different fertility levels and therefore Soil Test Crop Response - Integrated Plant Nutrition System (STCR-IPNS) based fertilizer prescription plays a vital role in ensuring balanced nutrition to crops. These prescriptions are of practical importance for efficient and judicious use of fertilizers in increasing crop production and prescription for desired yield target of crops could be made based on resource availability of farmers (Dey and Santhi, 2014).

On account of the above facts, the present investigation was undertaken with a view to refine the existing Fertilizer Prescription Equations under IPNS for hybrids to suit pearl millet variety on Periyanaickenpalayam soil series based on the response of pearl millet (var. CO 10).

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Material and Methods

Field experiment was conducted during rabi season of 2017-2018 at Eastern Block, Tamil Nadu Agricultural University, Coimbatore with the experimental crop pearl millet (var. CO 10). The soil of the experimental field belongs to Periyanaickenpalayam soil series, taxonomically Vertic Ustropept, sandy clay loam in texture and mixed black calcareous. The initial fertility status of surface soil was medium in organic carbon, low in available N, high in available P and K, sufficient in available Cu and Mn and deficient in available Fe and Zn. The experiment comprised of eleven treatments viz., T₁ – STCR-NPK alone - 3.0 t ha⁻¹, T₂ – STCR-NPK alone - 3.5 t ha⁻¹, T₃ – STCR-NPK alone - 4.0 t ha⁻¹, T₄ – STCR-IPNS- 3.0 t ha⁻¹, T₅ – STCR-IPNS-3.5 t ha⁻¹, T₆ – STCR-IPNS-4.0 t ha⁻¹, T₇ – FYM alone @6.25 t ha⁻¹, T₈ – FYM alone @12.5 t ha⁻¹, T₉ – blanket alone (100% RDF), T₁₀ – Blanket + FYM @12.5 t ha⁻¹, T₁₁ – Absolute control which were laid out in Randomized Block Design (RBD) with eleven treatments and three replications. For STCR treatments, the fertilizer doses were computed using the Fertilizer Prescription Equations developed under NPK alone and IPNS. For STCR-IPNS treatments, FYM was applied @ 12.5 t ha⁻¹ basally. The quantities of N, P and K contributed through FYM was subtracted from the inorganic fertilizer doses and applied for STCR - IPNS treatments. The crop was grown to maturity following all the improved package of practices for pearl millet.

The pre-sowing soil samples were collected from each plot before imposing the treatments and the processed soil samples were analysed for available N, P and K status following the standard procedures (Subbiah and Asija,1956); Olsen et al.,1954 and Standford and English,1949) respectively. The crop was harvested at its maturity and grain and straw yields were recorded. Plant and grain samples were collected at harvest, processed and analysed for their N, P and K contents and total uptake of N, P and K by pearl millet was computed. The experimental data was subjected to statistical analysis with a view to elucidate the effect of varying fertilizer doses of N, P and K and IPNS on yield and N, P and K uptake. Using the experimental data of STCR and FYM alone treatments and absolute control, the basic parameters viz., NR, Cs, CF were calculated by adopting the methodology developed by Ramamoorthy et al., (1967).

Nutrient requirement

Nutrient requirement is calculated as kg of N/P₂O₅/K₂O required per quintal (100 kg) of grain, expressed in (kg q⁻¹).

\[ NR = \frac{(\text{Total uptake of N or } P_2O_5 \text{ or } K_2O \text{ (kg ha}^-1\text{)) \text{ / Grain yield (q ha}^-1\text{))}} \]

Where NR= Nutrient requirement

Per cent contribution of nutrients from soil to total nutrient uptake (Cs)

\[ Cs = \frac{[(\text{Total uptake of N or } P_2O_5 \text{ or } K_2O \text{ in control plot (kg ha}^-1\text{)) / (\text{Soil test value for available N or } P_2O_5 \text{ or } K_2O \text{ in control plot (kg ha}^-1\text{))}] \times 100 \]

Per cent contribution of nutrients from fertilizer to total uptake (CF)

\[ CF = \frac{[(\text{Total uptake of N or } P_2O_5 \text{ or } K_2O \text{ in treated plot (kg ha}^-1\text{)) - (\text{Soil test value for available N or } P_2O_5 \text{ or } K_2O \text{ in control plot (kg ha}^-1\text{)) \times \text{Average Cs})]} \]

Fertilizer prescription equations

Using the refined basic parameters, the fertilizer prescription equations (FPEs) were developed for pearl millet (var.CO 10) as furnished below.

\[ STCR = \text{NPK alone} \]

\[ FN = \frac{[(\text{NR } / (\text{CF} / 100)) \times T] - [(\text{Cs/CF} \times \text{SN})]} {\text{[FYM/CF]*ON]} \]

\[ FP_{2O_5} = \frac{[(\text{NR } / (\text{CF} / 100)) \times T] - [(\text{Cs/CF} \times 2.29SP)]} {\text{[FYM/CF]*2.29OP}} \]

\[ FK_{2O} = \frac{[(\text{NR } / (\text{CF} / 100)) \times T] - [(\text{Cs/CF} \times 1.21SK)]} {\text{[FYM/CF]*1.21OK}} \]

Where, FN, FP₂O₅ and FK₂O are fertilizer N, P₂O₅ and K₂O in kg ha⁻¹ respectively; NR is nutrient requirement (N or P₂O₅ or K₂O) in kg q⁻¹, Cs is per cent contribution of nutrients from soil, CF is per cent contribution of nutrients from fertilizer, CFym is percent contribution of nutrients from FYM, T is the yield target in q ha⁻¹; SN, SP and SK respectively are alkaline KMnO₄-N, Olsen-P and NH₄OAc-K in kg ha⁻¹ and ON, OP and OK are the quantities of N, P and K supplied through FYM in kg ha⁻¹. These equations serve as a basis for predicting fertilizer doses for specific yield targets (T) of pearl millet (var.CO 10) for varied soil available nutrient levels.

Results and Discussion

Grain yield

Grain yield of the pearl millet ranged from 1180 to 3880 kg ha⁻¹ (Table 1). The highest grain yield (3880 kg ha⁻¹) was registered in T₈ (STCR-IPNS- 4.0 t ha⁻¹) which was on par with T₇ (STCR-NPK alone - 4.0 t ha⁻¹) with grain yield of 3790 kg ha⁻¹. Next to T₈ and T₇, significantly higher grain yield (3400 kg ha⁻¹) was observed in T₆ (STCR-IPNS-3.5 t ha⁻¹) and it was on par with T₁₀ (blanket + FYM @12.5 t ha⁻¹) and T₂ (STCR-NPK alone- 3.5 t ha⁻¹) by recording the
Table 1. Grain yield and nutrient uptake

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain Yield (kg ha⁻¹)</th>
<th>UN</th>
<th>UP</th>
<th>UK</th>
<th>SN</th>
<th>SP</th>
<th>SK</th>
<th>FN</th>
<th>FP,Ö</th>
<th>FK,Ö</th>
<th>FYM (t ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁, STCR – NPK alone – 3.0 t ha⁻¹</td>
<td>2710</td>
<td>72.91</td>
<td>14.33</td>
<td>57.71</td>
<td>181</td>
<td>24.2</td>
<td>463</td>
<td>92</td>
<td>44</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>T₂, STCR – NPK alone – 3.5 t ha⁻¹</td>
<td>3250</td>
<td>89.07</td>
<td>16.73</td>
<td>65.93</td>
<td>179</td>
<td>23.9</td>
<td>462</td>
<td>122</td>
<td>58</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>T₃, STCR – NPK alone – 4.0 t ha⁻¹</td>
<td>3790</td>
<td>107.53</td>
<td>21.92</td>
<td>69.75</td>
<td>184</td>
<td>23.9</td>
<td>466</td>
<td>152</td>
<td>72</td>
<td>39</td>
<td>0</td>
</tr>
<tr>
<td>T₄, STCR – IPNS – 3.0 t ha⁻¹</td>
<td>2850</td>
<td>77.17</td>
<td>14.97</td>
<td>58.98</td>
<td>183</td>
<td>23.6</td>
<td>461</td>
<td>50</td>
<td>19</td>
<td>20</td>
<td>12.5</td>
</tr>
<tr>
<td>T₅, STCR – IPNS – 3.5 t ha⁻¹</td>
<td>3400</td>
<td>92.48</td>
<td>18.36</td>
<td>66.40</td>
<td>182</td>
<td>24.0</td>
<td>463</td>
<td>80</td>
<td>33</td>
<td>20</td>
<td>12.5</td>
</tr>
<tr>
<td>T₆, STCR – IPNS – 4.0 t ha⁻¹</td>
<td>3880</td>
<td>110.07</td>
<td>24.83</td>
<td>71.51</td>
<td>180</td>
<td>24.0</td>
<td>465</td>
<td>110</td>
<td>47</td>
<td>20</td>
<td>12.5</td>
</tr>
<tr>
<td>T₇, FYM alone @ 6.25 t ha⁻¹</td>
<td>1880</td>
<td>52.34</td>
<td>12.34</td>
<td>57.11</td>
<td>182</td>
<td>23.1</td>
<td>456</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6.25</td>
</tr>
<tr>
<td>T₈, FYM alone @ 12.5 t ha⁻¹</td>
<td>2200</td>
<td>63.61</td>
<td>13.75</td>
<td>57.47</td>
<td>181</td>
<td>23.5</td>
<td>455</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12.5</td>
</tr>
<tr>
<td>T₉, Blanket 100% RDF</td>
<td>2410</td>
<td>69.93</td>
<td>14.07</td>
<td>57.58</td>
<td>182</td>
<td>23.4</td>
<td>456</td>
<td>70</td>
<td>35</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>T₁₀, Absolute control</td>
<td>3290</td>
<td>91.36</td>
<td>17.67</td>
<td>65.98</td>
<td>182</td>
<td>24.0</td>
<td>455</td>
<td>70</td>
<td>35</td>
<td>35</td>
<td>12.5</td>
</tr>
<tr>
<td>SEd</td>
<td>150</td>
<td>3.07</td>
<td>1.27</td>
<td>1.79</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>313</td>
<td>6.41</td>
<td>2.66</td>
<td>3.73</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Nutrient uptake

Grain yield of 3290 and 3250 kg ha⁻¹, respectively. Whereas T₁ (absolute control) recorded (1180 kg ha⁻¹) significantly lowest yield as compared to all other treatments (Table 1). Similar trend of grain yield was recorded in pearl millet (Neha et al., 2017).

Among the same yield targets, the grain yield under STCR-IPNS treatments was numerically higher than those under STCR-NPK alone due to application of NPK fertilizers along with FYM which might have provided a desirable soil condition for the root development, enhancing higher yield and nutrient uptake, crop growth and yield of maize (Sivarananji et al., 2018). This data clearly showed that along with inorganic fertilisers, organic manures also necessary to maintain optimum rhizosphere environment for sustaining pearl millet grain yield at higher level. Similar results were reported by Dapake (2014) and Neha et al. (2017).

Table 2. Basic parameters for pearl millet variety and fertilizer prescription equations

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Basic data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient requirement (kg q⁻¹)</td>
<td>2.81, 1.33, 2.53</td>
</tr>
<tr>
<td>Per cent contribution from soil (Cs)</td>
<td>26.36, 38.51, 10.33</td>
</tr>
<tr>
<td>Per cent contribution from fertilizers (Cf)</td>
<td>45.44, 44.14, 87.45</td>
</tr>
<tr>
<td>Per cent contribution from FYM (Cfym)</td>
<td>27.55, 16.04, 40.15</td>
</tr>
</tbody>
</table>

Nutrient uptake

The N, P and K uptake ranged from 43.63 to 110.07 kg ha⁻¹, 9.63 to 24.83 kg ha⁻¹ and 44.79 to 71.51 kg ha⁻¹, respectively. Among the eleven treatments, T₃ (STCR-IPNS- 4.0 t ha⁻¹) recorded the highest total N, P and K uptake (110.07, 24.83 and 71.51 kg ha⁻¹, respectively) and was found to be comparable with T₅ (STCR-NPK alone – 4.0 t ha⁻¹) with the uptake values of 107.53, 21.92 and 69.75 kg ha⁻¹, respectively. The lowest uptake of nutrients was registered in T₁ (absolute control) (Table 1). The uptake of N was 4.87 and 1.31 fold higher than P and K respectively. Similar increase in nutrient uptake due to increased fertilizer doses was also supported by the findings of Udayakumar and Santhi (2017). The significant increase in P uptake was due to higher levels of phosphorus application which would have led to higher root proliferation of the crop (Verma et al., 2014). The increased uptake may be attributed to solubility action of organic acids produced during decomposition of FYM resulting in more release of N, P and K and also to contribution by this manure (Dwivedi et al., 2016).

Response of pearl millet

The response of pearl millet to different doses of fertilizer N, P, O and K₃ was assessed. The response varied from 700 kg ha⁻¹ in FYM @ 6.25 t ha⁻¹ to 2700 kg in STCR-IPNS-4.0 t ha⁻¹. The data showed that irrespective of STCR-NPK alone or STCR-IPNS, there was a progressive increase in response from lower target to higher targets and the magnitude of response was higher under STCR-IPNS than under STCR-NPK alone treatments. This formed the basis to compute the basic parameters and develop the fertilizer prescription equations under IPNS for pearl millet variety.

Nutrient requirement, contribution of nutrients from soil, fertilizers and FYM

Using the pre-sowing soil available N, P and K, fertilizer doses applied, grain yield and total N, P and K uptake, the basic parameters viz., nutrient requirement (NR), contribution of nutrients from soil (Cs), fertilizers (Cf) and FYM (Cfym) were computed. The results emanated from the present investigation revealed that pearl millet var. CO 10 requires 2.81 kg N, 1.33 kg P, 0.1 and 2.53 kg K₃ for producing one
quintal of grain yield. The per cent contribution of N from soil was 26.36 and fertilizer was 45.44. With regard to P\textsubscript{2}O\textsubscript{5}, the percent contribution from soil was 38.51 and fertilizer was 44.14 while for K\textsubscript{2}O, the per cent contribution from soil was 10.33 and from fertilizer was 87.45 per cent. The per cent contribution of nutrients from FYM was 27.55, 16.04 and 40.15 per cent N, P\textsubscript{2}O\textsubscript{5} and K\textsubscript{2}O respectively (Table 2).

Table 3. Soil test based fertilizer N, P\textsubscript{2}O\textsubscript{5} and K\textsubscript{2}O for desired yield targets of pearl millet under NPK alone and IPNS (kg ha\textsuperscript{-1})

<table>
<thead>
<tr>
<th>Soil test values (kg ha\textsuperscript{-1})</th>
<th>3.0 t ha\textsuperscript{-1}</th>
<th>3.5 t ha\textsuperscript{-1}</th>
<th>4.0 t ha\textsuperscript{-1}</th>
<th>3.0 t ha\textsuperscript{-1}</th>
<th>3.5 t ha\textsuperscript{-1}</th>
<th>4.0 t ha\textsuperscript{-1}</th>
</tr>
</thead>
<tbody>
<tr>
<td>SN, SP, SK, FN, FP, OAc-K, FN, FP, OAc-K, FN, FP, OAc-K</td>
<td>STCR-NPK alone</td>
<td>STCR-IPNS</td>
<td>STCR-NPK alone</td>
<td>STCR-IPNS</td>
<td>STCR-NPK alone</td>
<td>STCR-IPNS</td>
</tr>
<tr>
<td>180 16 380 81 59 33 112 74 47 143 89 62 43 37 18 74 52 22 105 67 37</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 18 400 69 55 30 100 70 44 131 85 59 35 33 18 68 48 18 93 63 34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>220 20 420 58 51 27 89 66 41 119 81 56 35 29 18 51 44 18 81 59 31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>240 22 440 46 47 24 77 62 39 108 77 53 35 25 18 35 40 18 70 55 28</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>260 24 460 35 43 21 65 58 36 96 73 50 35 21 18 35 36 18 58 51 25</td>
<td></td>
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</tbody>
</table>

The extent of saving of inorganic fertilizers for pearl millet with the application of FYM @ 12.5 t ha\textsuperscript{-1} (with 21% moisture, 0.64 %, 0.27 % and 0.46 % NPK respectively) was 38, 22 and 25 kg of fertilizer N, P\textsubscript{2}O\textsubscript{5} and K\textsubscript{2}O respectively. The per cent reduction in NPK fertilizers under IPNS also increased with increasing soil available NPK status and decreased with increase in yield targets. Similar trend of results were reported by Coumaravel (2012) and Sivaranjani et al. (2018). The three yield target fixed in the treatments structure is to generate a database for computing basic parameters and develop fertilizer prescription equation. Therefore, using the experimental data

**Fig.1. Nutrient requirement (kg q \textsuperscript{-1})**

The data on NR, Cs, Cf and C\textsubscript{fym} clearly revealed that relatively higher quantity of N followed by K\textsubscript{2}O and P\textsubscript{2}O\textsubscript{5}. Since the soil K is high the contribution of K from Fertilizer K\textsubscript{2}O dominated a compared to soil K. The present findings corroborated with the findings of Udayakumar and Santhi (2017), Praveena Katharine et al. (2013) and Singh et al., (2015).

**Fertilizer prescription equations**

Making use of the basic parameters viz., NR, Cs, Cf and C\textsubscript{fym}, the Fertilizer Prescription Equations were developed under NPK alone and IPNS following the formulae as described earlier.

\[
\text{STCR-NPK alone} = \frac{\text{FN} + \text{FP} \times 0.58 \times \text{SN} + \text{SP} \times 0.58 \times \text{SK}}{0.61 \times \text{ON}}
\]

\[
\text{STCR-IPNS (NPK+FYM)} = \frac{\text{FN} + \text{FP} \times 0.58 \times \text{SN} + \text{SP} \times 0.58 \times \text{SK}}{0.61 \times \text{ON}}
\]

where, FN, FP, OAc-K, FN, FP, OAc-K and FK\textsubscript{O} are fertilizer N, P\textsubscript{2}O\textsubscript{5} and K\textsubscript{2}O in kg ha\textsuperscript{-1}, respectively; T is the grain yield target in q ha\textsuperscript{-1} and SN, SP and

SK respectively are alkaline KMnO\textsubscript{4}–N, Olsen-P and NH\textsubscript{4}OAc–K in kg ha\textsuperscript{-1}; ON, OP and OK are quantities of N, P and K in kg ha\textsuperscript{-1} supplied through FYM.

**Soil test based fertilizer doses**

Ready reckoners (nomograms) were formulated for a range of soil test values and for desired yield target of pearl millet under NPK alone and NPK plus FYM. A perusal of the estimate showed that when NPK alone was applied, for a soil test value of 180:24:460 kg ha\textsuperscript{-1} of KMnO\textsubscript{4}–N, Olsen-P and NH\textsubscript{4}OAc-K respectively, the fertilizer N, P\textsubscript{2}O\textsubscript{5} and K\textsubscript{2}O doses required to achieve a desired yield target of 3.0, 3.5 and 4.0 t ha\textsuperscript{-1} were 81, 43 and 21 kg ha\textsuperscript{-1}; 112, 58 and 36 kg ha\textsuperscript{-1} and 143, 73 and 50 kg ha\textsuperscript{-1} respectively. Whereas the fertilizer N, P\textsubscript{2}O\textsubscript{5} and K\textsubscript{2}O doses required when FYM @ 12.5 t ha\textsuperscript{-1} was applied along with NPK, the required fertilizer doses were 43, 21 and 18 kg ha\textsuperscript{-1}; 74, 36 and 18 kg ha\textsuperscript{-1} and 105, 51 and 25 kg ha\textsuperscript{-1} (Table 3).

**Fig.2. Per cent contribution of nutrients from soil, fertilizer and FYM**
of the present investigation, the existing fertilizer prescription equations under IPNS for pearl millet hybrids were refined to suit pearl millet variety (CO 10) on Periyanaickenpalayam soil series - Vertic Ustropept of Tamil Nadu so as to prescribe fertilizer doses for desired yield targets.

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Received : May 11, 2018; Revised : June 18, 2018; Accepted : June 25, 2018