Effect of crop diversification and residue management techniques on yield attributes, yield and soil nutrient

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Abstract
Green revolution prompts the development of rice wheat cropping system over the South Asian Indo-Gangetic Plains. This system is comprehensive in nature and prompts malicious consequences on soil health which is the most disturbing issue these days and the other issue which takes individuals consideration is the the loads of residue generation. To Find the potential approaches to counter these issue an examination was directed at held during the Kharif season of 2017 at N. E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, US Nagar, Uttarakhand. This study has been notified that the crop diversification through legumes leads to better soil property and increases the yield.

Keywords: Diversification, Revolution and approaches

Introduction
Rice-wheat cropping system (RWCS) is most dominant and mainstay of food self-sufficiency in many Asian countries by contributing 23% of food grain production (Verma et al., 2016) [27]. It covers an area of 13.5 million hectares across South Asian Indo-Gangetic Plains (IGP) (Ladha et al., 2003) [16] and is the spine of social and economic growth of millions of people (Chauhan et al., 2012) [5]. However, this system has shown the sign of stagnant yield and declining soil health. The sustainability of the system has been questioned due to yield stagnation, soil health deterioration in the environment for more than two decades now (Das et al., 2017) [6]. Conventional RWCS leads to loads of issues such as ecological (declining underground water level, groundwater contamination, diverse weed flora, disease outbreak and insect pest); farming (degrading soil structure, declining soil health, residue management, least attended interim period, labor shortages, multiple nutrient deficiencies, declining crop response); livelihood (high energy requirement, reduce land productivity, lower water production, lower water efficiency, low wages) and climate (environmental pollution and global warming) (Bhatt et al., 2016) [13]. Intensive tillage, removal or burning of rice residues accelerates soil erosion, contamination of the atmosphere, soil depletion and affects functions of the ecosystem (Srinivasan et al., 2012) [23]. These constraints are widely found in rice-based cropping systems in the Indo-Gangetic plain where poor residue management, extensive fertilizer use and lack of diversification are normal practice. Sustainable module therefore requires an hour not only to mitigate these constraints but also to boost the efficiency of the ricebased cropping system for a projected 1.3 billion population increase by 2025 in India (UNEP, 2008) [25]. Residue is another challenge which needs attention, particularly at RWCS. Approximately 500 Mt of crop residues are produced annually according to the MNRE report (Agarwal et al., 2016) [1]. Cereal crops (corn, wheat, maize, millets) contribute 70% of the residue produced, while corn crops alone contribute 34% to crop residues, while wheat ranks second with 22% of crop residue. Hence, the removal of residues may have a direct effect on the depletion of soil nutrients. Residue control also affects the supply of micronutrients such as zinc and iron, which is an important factor in preserving the total balance of Silicon in rice (Dobermann which Fairhurst, 2000) [8]. Burning the rice residues causes environmental pollution, global warming, killing beneficial insects, generating net negative nutrient
balance and also degrading the soil, reducing levels of organic matter and eventually contributing to degradation of soil health. Rice straw burning gaseous emissions are 70 percent CO₂, 7 percent CO, 0.66 percent CH₄ and 2.09 percent N₂O. Roughly 12 Mt of rice straw is burned annually in Punjab alone, which causes about 0.7 Mt of N losses (Samra et al., 2003) [21]. Alternative uses for rice straw management are possible to ensure maximum benefit without burning rice residues, for example using crop residues for manure, energy production, ethanol, biogas, residue gasification, pyrolysis (Yadwinder & Sindhu, 2014) [28]. Residue incorporation also improves aggregate stability (Keller et al., 2007) [10] and total porosity, resulting in increased soil moisture content as well as availability of water content (Jemai et al., 2013) [13], with residue incorporation also improves aggregate stability (Keller et al., 2007) [10] and total porosity and as a result, soil moisture content increases, as well as the amount of water content (Jemai et al., 2013) [13]. In view of all these issues and problems with the traditional rice wheat program, there is an urgent need to develop a technology that can resolve the issue of crop diversification and intensification and better use of crop residues for soil fertility improvement. In view of this, the present experiment was conceived with three different types of cropping method i.e. Rice- wheat, Rice- vegetable pea- maize (cob + fodder) and Rice- yellow sarson-groundnut by intensifying and diversifying crops to improve both soil and crop productivity.

Material and methods

Experimental detail

Experiment was conducted in Split Plot Design with three cropping systems viz. rice-wheat, rice-wheat-vegetable pea-maize and rice-yellow Sarson-groundnut in main plot and five residue management techniques viz. farmer’s practice, 30% residue recycling, 30% residue recycling + FYM @ 5 t ha⁻¹, 30% residue recycling + Biogas slurry @ 2 t ha⁻¹ and 30% residue recycling + Vermicompost @ 2 t ha⁻¹ replicated thrice. The residue was incorporated in the field in all the treatments except control (C₁,T₁, C₂T₂ and C₃T₃). Based on crop rotation, 30 % crop residue of the preceding crop was incorporated i.e. 30 % of the total residue produced as depicted below. The residue was incorporated by ploughing followed by harrowing.

| Crop   | Residue produced (q/ha) | Amount applied (q/ha) | Date of residue application |
|--------|-------------------------|-----------------------|-----------------------------|
| Wheat  | 60                      | 18                    | 15/04/2017                  |
| Groundnut | 40.5                   | 12.15                 | 28/06/2017                  |
| Maize  | 116.7                   | 35.01                 | 18/06/2017                  |
| Organics | C%                     | N%                     | P%                         | K % | C:N   |
| FYM    | 16.2                    | 0.59                   | 0.26                       | 0.60 | 27    |
| Vermicompost | 24.5                 | 1.21                   | 0.78                       | 0.90 | 20    |
| Biogas slurry | 15.96               | 1.05                   | 0.45                       | 0.55 | 15    |

The organics used in the experiment were FYM, vermicompost and biogas slurry. FYM @ 5 t/ha, vermicompost @ 2/ha and biogas slurry @ 2/ha; was applied just before puddling as per the treatment so that it gets mixed in the soil. The samples of organics were taken and through laboratory analysis, the N, P and K percentage present in organics was calculated.

The treatments were replicated with size 3x8.3 m². Twenty-two days old rice seedlings of “HKR-47” were transplanted in July. In all the treatments nitrogen, phosphorus, potassium and zinc were supplied through urea, diammonium phosphate, muriate of potash and zinc sulphate, respectively. The nitrogen is applied in three split doses. Entire P and K and 50kg N were applied as basal. However, the 1st top dressing was done at 28 DAT and 2nd top dressing was done at 49 DAT through Green seeker. The foliar zinc was sprayed 10 and 20 days after transplanting of rice. Harvesting was done manually when more than 90 per cent of grains in the panicle were fully ripe and free from greenish tint. The observation for growth, development was recorded from the sampling area under field condition.

Yield attributes

Yield attributing were recorded at maturity is given in table 1. Number of panicles m⁻² was counted. The total number of grain per panicle was calculated by dividing the total number of grain to the total number of panicles. The panicle length measured with the help of meter scale in centimetre. One thousand grains were counted from each plot and weighed to get thousand grains weight in grams. Ten panicles were harvested and threshed manually. After cleaning and drying the weight was recorded and converted to m⁻². The grain weight per panicles was obtained by grain weight m⁻² divided by number of panicles m⁻². Grain yield is obtained after threshing and cleaning. The grain yield was converted to t ha⁻¹ after adjusting grain moisture at 10%.

Soil parameters

Composite soil sample of each plot was collected by core from 0-15 cm. The samples were air dried in shade on polythene sheets. After drying, samples were crushed on hard wooden slab with the help of wooden roller and passed through 2 mm sieve and stored in labelled polythene bags for further chemical analysis. Available N was determined by alkaline KMnO₄ method given by Subbiah and Asija (1956) [24]. Available P was extracted by Olsen’s method (Olsen et al., 1954) [19]. Available K in soil was determined by extraction with 1 N ammonium acetate of neutral pH and K concentration in soil extract was determined by flame photometer (Hanway and Heidel, 1952) [11]. Soil parameter is given in table 2.

Result and discussion

Yield and Yield attributes

Residue management through organics and diversification through legumes have significant effect over different yield parameter and grain yield. The number of panicles m⁻² was recorded maximum in C₁ which was significantly higher than C₁ and C₂. The percent increase in number of panicles in C₁ was 7.22 and 3.48 percent over C₁ and C₂, respectively. The maximum grain yield was observed under C₁ (28.0 cm) and was at par with C₂. The minimum panicle length was observed in C₁ (26.0). However, there was no significant response of number of grain panicle¹ and thousand grain weights (g). The maximum grain weight panicle¹ was notified in C₁ (3.2g). The percent increase in grain weight panicle¹ in C₂ was 14.3 and 10.3 per cent over C₁ and C₂, respectively. The maximum grain yield was observed under C₁ but was statistically at par with C₂. The percent increase in the grain yield in C₁ over C₁ is 11.23%. Diversification through legumes results in addition of nitrogen to the soil through biological nitrogen fixation thereby help in enhancing the nutrient availability, enhances the microbial activity (numbers of bacteria, fungi, and actinomycetes) and results in
better growth and yield supported by (Davari et al., 2002) [7]. They reported that under rice-wheat-maize cropping system (RWMC) the activity of microbes were higher i.e. numbers of bacteria, fungi, and actinomycetes in soil and improves soil health than under rice-wheat cropping system (RWCS) and results in higher number of panicles m⁻². Further, supported by Sharma and Sharma, 2003 [22] that after two cycles of rice-potato-mungbean, rice-wheat-mungbean, rice-rapeseed-mungbean and rice-clover cropping systems, respectively results in better availability of nutrients and increased the number of panicle m⁻², panicle length, number of grains per panicle, grain weight panicle⁻¹ and thousand grain weight.

Table 2: Yield attributes of rice as influenced by different cropping sequence and residue management techniques

| Treatments                          | Number of panicle m⁻² | Panicle length (cm) | Number of grain panicle⁻¹ | Grain wt. Panicle⁻¹ (g) | 1000 grain wt. (g) | Grain yield (t ha⁻¹) |
|-------------------------------------|-----------------------|---------------------|---------------------------|--------------------------|--------------------|----------------------|
| **Cropping System**                 |                       |                     |                           |                          |                    |                      |
| T¹- Farmer’s practice               | 261                   | 25.5                | 81                        | 2.8                      | 29.2               | 5.42                 |
| T₂-30% residue recycling            | 272                   | 26.9                | 81                        | 2.9                      | 29.6               | 5.35                 |
| T₃- T₂+FYM                          | 300                   | 27.2                | 82                        | 3.0                      | 29.8               | 6.45                 |
| T₄-T₂+biogas slurry                 | 296                   | 28.3                | 83                        | 3.0                      | 29.8               | 6.38                 |
| T₅-T₁+vermicompost                  | 306                   | 29.3                | 84                        | 3.1                      | 30.1               | 7.12                 |
| SEm (+)                             | 4.29                  | 0.46                | 0.44                      | 0.05                     | 0.07               | 0.11                 |
| CD at 5%                            | 12.53                 | 1.34                | 1.29                      | 0.15                     | 0.19               | 0.33                 |
| **Residue management techniques**   |                       |                     |                           |                          |                    |                      |
| T₁- Farmer’s practice               | 261                   | 25.5                | 81                        | 2.8                      | 29.2               | 5.42                 |
| T₂-30% residue recycling            | 272                   | 26.9                | 81                        | 2.9                      | 29.6               | 5.35                 |
| T₃- T₂+FYM                          | 300                   | 27.2                | 82                        | 3.0                      | 29.8               | 6.45                 |
| T₄-T₂+biogas slurry                 | 296                   | 28.3                | 83                        | 3.0                      | 29.8               | 6.38                 |
| T₅-T₁+vermicompost                  | 306                   | 29.3                | 84                        | 3.1                      | 30.1               | 7.12                 |
| SEm (+)                             | 4.29                  | 0.46                | 0.44                      | 0.05                     | 0.07               | 0.11                 |
| CD at 5%                            | 12.53                 | 1.34                | 1.29                      | 0.15                     | 0.19               | 0.33                 |

Among the different residue management techniques, the maximum number of panicles m⁻² were obtained in T₅ (306) which were significantly higher than T₁ and T₂ but was statistically at par with T₃ and T₄. The number of panicles m⁻² in T₅ was increased to the tune of 17.24 percent, respectively over T₁. The maximum panicle length was observed in T₅ (29.3cm) and the minimum was under T₁ (25.5cm). T₃ and T₁ have statistically similar panicle length. The maximum, number of grains panicle⁻¹ and grain weight panicle was observed in T₅ i.e. 84 and 3.1g respectively and which was increased by 3.70 and 10.71 percent, respectively over T₁. However, significantly higher thousand grain weight was observed in T₅ above all the other residue management techniques using organics. The thousand grain weight was increased in T₅ to the tune of 3.08 percent, respectively over T₁. grain yield was significantly higher in T₅ than all other treatments. The lowest grain yield was observed in T₂ (30 % residue recycling) which was at par with T₁ (farmer’s practice). The increase in grain yield in T₃ over T₁ was 31.36%. Among residue management techniques through organics the yield attributes increased. Number of panicles m² were higher due to higher number of shoots per m² whereas, the better height and dry matter production helps in proper photosynthesis and translocation of photosynthates whereas, the nutrient availability was also higher due to incorporation of residue + organics which might have resulted in enhanced yield attributes. Bilkis et al. (2015) [4] at Bangladesh reported that, maximum number of tiller hill⁻¹, panicle length, grain panicle⁻¹ and 1000 grain weight was observed in tricompost + chemical fertilizer but was statistically at par with vermicompost + chemical fertilizer followed by cow dung slurry + chemical fertilizer. Haque et al. (2014) [12] reported that effective tillers hill⁻¹, panicle length and grains panicle⁻¹ and 1000-grain weight were enhanced significantly due to the application of organics along with soil test based chemical fertilizers over control. Bejbaruah et al. (2013) [2] reported that yield attributes i.e. number of panicles m⁻² was significantly increased by application of vermicompost (VC). Lungmuana et al. (2016) [17] reported that, the length of panicle of rice was significantly higher under integrated use of vermicompost and chemical fertilizer over control.

Fig 1: Grain, straw and biological yield as influenced by different cropping system
Soil nutrient
Among different diversified treatments the highest available nitrogen in soil was registered under C3 (230.07 kg ha\(^{-1}\)) which was significantly higher in C1 but was statistically at par with C2. Available soil nitrogen in C3 and C2 was increased by 11.18 and 4.64 percent, over C1. The same trend is followed in available potassium in the soil. The maximum available soil potassium was under C3 which was increased to the tune of 24.3 percent over C1. However, the available phosphorus was significantly higher in C1 (20.3 kg ha\(^{-1}\)) than C2 and C1, respectively. Available soil phosphorus in C3 and C2 was increased by 24.05 and 2.88 percent, respectively over C1. Among different residue management techniques, the T3 was significantly higher available soil nitrogen, phosphorus and potassium than T1, T2 and T3 but was statistically at par with T4. In residue management techniques i.e. T3 available nitrogen in soil was increased to the tune of 17.16 percent respectively; available phosphorus in soil was increased by 41.73 percent respectively; whereas available potassium in soil was increased to a tune of 52.73 percent, respectively over T1.

Table 3: Available nitrogen, phosphorus and potassium in soil (kg ha\(^{-1}\)) as influenced by different cropping sequence and residue management techniques

| Treatments                  | Available soil nutrients (kg ha\(^{-1}\)) | N   | P   | K   |
|-----------------------------|------------------------------------------|-----|-----|-----|
| Cropping System             |                                          |     |     |     |
| C1- Rice-wheat              |                                          | 206.93 | 16.30 | 130.69 |
| C2- Rice-vegetable pea-maize|                                          | 219.53 | 16.80 | 161.09 |
| C3- Rice-yellow sarsan-groundnut|                                      | 230.07 | 20.30 | 162.49 |
| CD at 5%                    |                                          | 17.01 | 2.10 | 16.49 |
| Residue management techniques|                                          |     |     |     |
| T1- Farmer’s practice        |                                          | 201.44 | 14.76 | 114.70 |
| T2- 30% residue recycling    |                                          | 208.00 | 16.18 | 136.44 |
| T3- T2 + FYM                |                                          | 220.89 | 17.95 | 160.09 |
| T5- T2 + biogas slurry      |                                          | 227.89 | 19.22 | 170.67 |
| T5- T2 + vermicompost       |                                          | 236.00 | 20.92 | 175.18 |
| CD at 5%                    |                                          | 3.68  | 0.94 | 2.54  |

Crop diversification through legumes and residue management through organics showed higher available soil NPK. The probable reason might be due to higher organic matter in the soil because of residue incorporation in every season. Legumes have the ability of biological nitrogen fixation (BNF), leaf shedding, and higher root biomass, can enrich soil organic carbon (SOC), soil fertility, and redistribute of nutrients in the soil profile (Ganeshamurthy 2009; Kamanga et al. 2014) [9,14]. The poor SOC stock in soils is one of the main reasons for poor soil nutrient supply (Mandal et al. 2007) [18] pulse crop residue with lower C:N ratio could serve as important plant nutrient source and recycling of these residues help in supplying the nutrient demand of the crop (Grant et al. 2002) [19] and therefore residue of pulse crop increases the available nutrient in the soil. Including pulses in rotation may significantly effects the nutrient cycling in the soil–plant system because of its influence on soil residual fertility, and nutrient acquisition by the next crop in the rotation Vankatesh et al. (2017). Porpavai et al. (2011) [20] at Thanjavur reported that inclusion of legume in rice-based cropping sequence contributed 0.04% increase in organic carbon. Sharma and Sharma (2003) [22] reported that, available N content in soil decreased by 1.5 kg ha\(^{-1}\) after two cycles of rice-wheat cropping system but increased by 9.6, 13.8 and 14.1 and 3.5 kg ha\(^{-1}\) after two cycles of rice-potato-mungbean, rice-wheat-mungbean, rice-rapeseed-mungbean and rice-clover cropping systems, respectively.

Conclusion
Diversification of rice-wheat system as rice-yellow sarsan-groundnut and rice-vegetable pea-maize and residue managements techniques where the organics are used to increase the rate of decomposition of the residue by lowering the C:N ratio results in increased number of panicle m\(^{-2}\), panicle length, number of grain panicle\(^{-1}\), grain wt. panicle\(^{-1}\) results in better grain yield. Among these residue management techniques the treatment where 30% residue management through vermicompost @ 2 t ha\(^{-1}\) was applied performed best in terms of both yield and soil nutrient availability.

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