Effect of rice residue management and crop diversification on growth and yield of rice

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Abstract

RWCS is the most dominant and extensive cropping system across South Asian Indo-Gangetic Plains. It has the deleterious effects on the soil physical properties and leads to ample amount of residue generation. Residue management is the biggest question that arises thereby to overcome these problems and to maintain the sustainability an experiments was 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, Uttarakhad situated at 29°N, 79°29'E and at an altitude of 243.86 above mean sea level, to evaluate the effect of crop diversification and residue management techniques through organics on rice growth and productivity. It has been observed that diversification of RWCS as rice-yellow saron-groundnut and rice-vegetable pea-maize along with 30% residue management through organics viz., vermicompost @ 2 t ha⁻¹, FYM @ 5 t ha⁻¹ and biogas slurry @ 2 t ha⁻¹ can be advocated for enhancing the growth and productivity of rice and the 30% residue management through organics viz., vermicompost @ 2 t ha⁻¹ and rice-yellow saron-groundnut perform best among them with the grain yield of 7.12 t ha⁻¹ and 6.44 t ha⁻¹, respectively.

Keywords: Diversification, Sarson-groundnut and organics

Introduction

Rice-wheat cropping system is the foremost production system covering an area of 13.5 million hectares across South Asian Indo-Gangetic Plains (IGP) (Ladha et al., 2003) and feeds about one-fifth of the world population. In Asian nations, this framework represented around 32% and 42% region of the complete rice and wheat, individually (Memon et al., 2018) (14). Capital and vitality concentrated traditional administration rehearses for rice and wheat development puts this life-supporting creation framework on a ventilator. Supportability of rice and wheat creation is under risk because of monotonous husbandry in a similar territory of field. Henceforth, the efficiency upgrade of RWCS is the prime essential to take care of the quickly expanding population of India, which is anticipated to increment to 1.35 billion by 2025 (UNEP, 2008) (23).

Crop diversification through the incorporation of legume in cereal have supplementary advantages well beyond the addition of nitrogen through biological nitrogen fixation including improved soil fertility and mitigate the impact nutrient mining and along with breaking the monotonity of rice-wheat production system (Bezner Kerr et al., 2007; Wani et al., 1995) (2, 17). Legumes incorporation in a framework expands grain yield of resulting crop, and subsequently improves the SOC in legume-cereal rotation. An increase in SOC by more than two-folds within 13 years of rice-wheat annual rotation when legumes were integrated into a crop rotation (Rekhi et al., 2000) (17).

On-farm burning is the common practice followed by farmers for clean cultivation, adoption of farm mechanics and pest management. According to National Policy for Management of Crop Residues, the crop residue generation is highest in Uttar Pradesh (60 Mt) followed by Punjab (51 Mt) and Maharashtra (46 Mt) with a grand total of 500 Mt per year (Bhuwaneshwari et al., 2019) (3). In India according to IPCC over 25% of the total crop residues were burnt on the farm major contribution was 43% of rice, followed by wheat (21%), sugarcane (19%) and oilseed crops (5%). Open agricultural crop residues, burning to release a great number of pollutants to
the atmosphere, which includes aerosols and hydrocarbons (Tripathi et al., 2013) [24]. So, to overcome this residue recycling is the best possible way out.

Residue incorporation also improves aggregate stability (Keller et al., 2007) [10] and porosity, infiltration, water holding capacity and water availability (Jemai et al., 2013) [9]. Residue recycling also influences the availability of macro and micronutrients such as zinc and iron, and it is an important factor in maintaining the cumulative Silicon balance in rice (Dobermann and Fairhurst, 2000) [7]. However, 100% of residues incorporation of cereals is very difficult to use as the C: N ratio of the residue is very high. Hence, there is an urgent need to develop a technology to efficiently use the crop residue. Therefore, the organics like well-decomposed farmyard manure, vermicompost which have the lower C: N ratio were mixed with crop residue to lower down the C: N ratio to overcome temporary immobilization of plant nutrients (Davari et al., 2012) [6]. It is observed that the organic manure incorporation with crop straw into soil enhances the soil properties like better aggregation, improves nutrient availability and increases crop yield (Enjei et al., 2001; Singh et al., 2001) [8, 21]. Crop residue recycling is an essential component in achieving sustainability; improvement in soil condition not necessarily always flows to yields (Singh et al., 2005) [20].

Material and Method
Experimental Detail

Experiment was conducted in Split Plot Design with three cropping systems viz. rice-wheat, rice-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, C₂ and C₃). 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                 |

The organics used in the experiment were FYM, vermicompost and biogas slurry. FYM @ 5t/ha, vermicompost @ 2t/ha and biogas slurry @ 2t/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.

| Organics       | C%  | N%  | P%  | K%  | C: N |
|----------------|-----|-----|-----|-----|------|
| FYM            | 16.2| 0.59| 0.26| 0.50| 27   |
| Vermicompost   | 24.5| 1.21| 0.78| 0.90| 20   |
| Biogas slurry  | 15.96| 1.05| 0.45| 0.55| 15   |

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.

Growth Attributes

Growth attributes were recorded at maturity is given in table 1. Shoot height (cm) was measured with a meter scale from the base of the plants to the tip of the panicle. Number of shoots per meter square was recorded. For determining the dry matter accumulation, crop samples were clipped closed to the ground and collected in polythene bags. The plants were then washed with water and collected in paper bags thereafter, the plants were dried in drier at 70 ± 2°C temperatures for 48-72 hours up to constant weight. After drying, their weights were recorded. The weight thereafter converted into gram dry matter per square metre (gm²).

Yield

Biomass weight of sun-dried crop from net plot was considered as biological yield which was further converted into tons per hectare (t ha⁻¹). Yield attributes were given in table 2. Grain yield is obtained after threshing and cleaning. The grain yield was converted to t ha⁻¹ after adjusting grain moisture at 10%. Straw yield per plot was obtained by subtracting the grain yield from biological yield produced per plot and converted to t ha⁻¹ after adjusting straw moisture at 14%. The harvest index is determined by dividing the total grain yield and the total biological yield. Yield parameters are given in table 2.

Result and Discussion

Growth Attributes

The growth attributes were significantly affected by diversification and the residue management. Shoot height, number of shoots m⁻² and dry matter accumulation (g m⁻²) were significantly higher under C₁ (rice-yellow sarsongroundnut cropping system) over under C₂ (rice-vegetable pea-maize cropping system) and C₁ (rice-wheat cropping system). Lowest shoot height was observed under C₁. Shoot height in C₁ was 3.97% higher than the C₂. Number of shoots m⁻² and dry matter accumulation was statistically at par with C₂. The least number of shoots m⁻² and dry matter accumulation was observed C₁ i.e. 285 and 1393.3g m⁻², respectively.

Pulses have the capability to fix the atmospheric nitrogen through biological nitrogen fixation. Inclusion of legumes in the cropping system as it add nitrogen to the soil through biological nitrogen fixation thereby improves soil health and resulted in better growth of the rice such as plant height, dry matter accumulation, number of shoots which is supported by Davari et al. (2002) [5] who reported that the N content, microbial population i.e. numbers of bacteria, fungi, and actinomycetes in soil was higher under rice-wheat-maize cropping system (RWMCs) than under (RWCS) rice-wheat cropping system thereby results in maximum shoot height and dry matter production of rice under (RWMCs). Porpavai et al. [2001; Singh et al., 2001] [8, 21]. Crop residue recycling is an essential component in achieving sustainability; improvement in soil condition not necessarily always flows to yields (Singh et al., 2005) [20].
al. (2011) \[16\] at Thanjavur reported that inclusion of legume in organic-based cropping system contributed 0.04\% increase in organic carbon thereby providing better nutrient supply and increased the number of shoots and dry matter accumulation of crop. Sharma and Sharma (2003) \[19\] reported the enhanced growth of rice crop i.e. shoot height, number of shoots by crop diversification as the 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. As the shoot height, a number of shoots and dry matter accumulation of the crop increases, the photosynthetic area also increases results in higher photosynthesis which leads to a higher yield of the crop. (Sharma and Sharma, 2005) \[18\] reported that the inclusion of legume i.e. mungbean in the rice-wheat system results in higher productivity and profitability.

Table 3: Growth attributes of rice as influenced by different treatments at different stages of crop growth

| Treatments                              | Shoot height (cm) | Number of shoots m\(^{-2}\) | Dry matter accumulation (g m\(^{-2}\)) |
|-----------------------------------------|-------------------|-----------------------------|---------------------------------------|
| Cropping System                         |                   |                             |                                       |
| C\(_1\)-Rice-wheat                     | 125.8             | 285                         | 1393.3                                |
| C\(_2\)-Rice-vegetable pea-maize       | 127.4             | 298                         | 1435.6                                |
| C\(_3\)-Rice-yellow sarson-groundnut    | 130.8             | 307                         | 1505.2                                |
| SEm (+)                                 | 0.90              | 4.14                        | 21.34                                 |
| CD at 5%                                | 3.54              | 16.3                        | 83.80                                 |
| A. Residue management techniques       |                   |                             |                                       |
| T\(_1\)-Farmer’s practice               | 125.3             | 273                         | 1400.2                                |
| T\(_2\)-30% residue recycling           | 126.3             | 278                         | 1404.9                                |
| T\(_2\)-T\(_1\)+FYM                    | 128.0             | 305                         | 1466.8                                |
| T\(_2\)-T\(_2\)+biogas slurry          | 130.2             | 304                         | 1458.8                                |
| T\(_2\)-T\(_2\)+vermicompost           | 130.1             | 321                         | 1492.8                                |
| SEm (+)                                 | 1.32              | 3.39                        | 18.85                                 |
| CD at 5%                                | 3.85              | 9.9                         | 55.03                                 |

Among the different residue management techniques T\(_3\) (biogas slurry @ 2 t ha\(^{-1}\) + 30\% residue recycling) was significantly higher than different treatments but was at par with T\(_2\) (30\% residue recycling), T\(_3\) (FYM @ 5 t ha\(^{-1}\) + 30\% residue recycling) and T\(_3\) (vermicompost @ 2 t ha\(^{-1}\) + 30\% residue recycling). The percent increase in shoot height in T\(_4\) (biogas slurry @ 2 t ha\(^{-1}\) + 30\% residue recycling) over T\(_1\) (farmer’s practice) was 3.91\%, which might be due to the increased mineralization rate of biogas slurry than vermicompost and the FYM supported by the study which revealed that application of biogas slurry and bio-mineralizer increases the rate of residue decomposition (narrow C:N) and was statistically par with T\(_3\) (FYM @ 5 t ha\(^{-1}\) + 30\% residue recycling) and T\(_4\) (biogas slurry @ 2 t ha\(^{-1}\) + 30\% residue recycling). The increase in dry matter accumulation m\(^{-2}\) was 6.61\% over C\(_1\) (rice-wheat cropping system), respectively. The C:N ratio of the crop residue is very high and its incorporation into the field leads to temporary immobilization but the incorporation of vermicompost, biogas slurry and FYM lowers the C:N ratio and results in faster decomposition of the residue which improves the nutrient status of the soil and these organics also add nutrient to the soil and improves the soil properties. Therefore, results in better availability of nutrient to the crop. Similar results were reported by Bilkis et al. (2015) \[4\] that the maximum plant height, number of shoots, dry matter accumulation and other growth attributing characters was observed in tricompost + chemical fertilizer but was statistically at par with vermicompost + chemical fertilizer followed by cow dung slurry + chemical fertilizer supported by Srivastava et al. (2014) \[22\]. They observed that the integration of organics and inorganics sources of nutrients regulates the balanced supply of nutrients in adequate quantity over prolonged period of crop growth and also reported that continuous supply of balanced quantity nutrients throughout the growth stages enabled the plant to assimulate sufficient amount of photosynthetic product and thus increased the dry matter accumulation. Similar results were found by Sudhakar et al. (2006) \[23\] for rice crop.

Yield

Diversification and the residue management techniques have the significant effect on the yield components. The maximum grain yield was observed under C\(_3\), but was statistically at par with C\(_2\). The percent increase in the grain yield in C\(_3\) over C\(_1\) is 11.23\%. The straw yield and the biological yield were maximum in C\(_3\), i.e. 8.30 and 14.74 t/ha, respectively followed by C\(_2\) and C\(_1\). There were no significant difference in terms of harvest index and grain: straw ratio. Diversification of rice wheat cropping system enhances the growth of the plant which results in better productivity.

Table 4: Yield of rice as influenced by different cropping system and residue management techniques

| Treatments                              | Yield (t ha\(^{-1}\)) | Harvest Index | Grain: Straw |
|-----------------------------------------|-----------------------|---------------|--------------|
| C\(_1\)-Rice-wheat                      | 5.79                  | 13.01         | 44.50        |
| C\(_2\)-Rice-vegetable pea-maize       | 6.21                  | 14.06         | 43.12        |
| C\(_3\)-Rice-yellow sarson-groundnut    | 6.44                  | 14.74         | 44.61        |
| SEm (+)                                 | 0.19                  | 0.12          | 0.59         |
| CD at 5%                                | 0.36                  | 0.48          | NS           |
| B. Residue management techniques       |                       |               |              |
| T\(_1\)-Farmer’s practice               | 5.42                  | 12.58         | 43.28        |
| T\(_2\)-30% residue recycling           | 5.35                  | 12.43         | 43.11        |
| T\(_2\)-T\(_1\)+FYM                    | 6.45                  | 14.50         | 44.46        |
| T\(_2\)-T\(_2\)+biogas slurry          | 6.38                  | 14.13         | 45.14        |
| T\(_2\)-T\(_2\)+vermicompost           | 7.12                  | 16.05         | 44.40        |
| SEm (+)                                 | 0.11                  | 0.22          | 0.53         |
| CD at 5%                                | 0.33                  | 0.65          | NS           |

Within the different residue management techniques, grain yield was significantly higher in T\(_3\) than all other treatments. The lowest grain yield was observed in T\(_2\) (30\% residue recycling) which was at par with T\(_1\) (farmer’s practice). The increase in grain yield in T\(_3\) over T\(_1\) was 31.36\%. The
maximum straw and biological yield was observed in T5 which is significantly higher than other treatments. The percent increase in straw and biological yield over control (T1) was 25.07 and 27.9%, respectively. The effect of residue management technique was non-significant in terms of harvest index and grain: straw ratio. The organic applied treatments results in the better growth of the crop due to long term availability of nutrients due to their slow release pattern of organics. Among organics, vermicompost perform better due to its slowest release pattern and higher nutrient percentage. Similar results were shown by Davari and Sharma (2012) [9]. They reported that among different treatments i.e. FYM @ 60 kg N ha⁻¹; FYM + rice residue @ 6 t ha⁻¹ (RR); FYM + RR + bio fertilisers (B); vermicompost @ 60 kg N ha⁻¹ (VC); VC + RR and VC + RR + B, the application of vermicompost + crop residue + bio fertilisers showed highest grain. While comparing the different treatment availability of NPK was significantly higher in vermicompost treated plots than FYM reported by Barik et al. (2006) [10] but among different organics, biogas slurry was least effective due to its faster N release pattern, which enabled maximum nitrogen availability only up to 30 days coincides with tillering stage similar result was reported by Kumar et al. (2018) [11], Lungmuana et al. (2016) [12] reported that the grain and straw yield of rice was significantly higher under the treatment combination of chemical fertilizer + vermicompost over control and followed by chemical fertilizer + FYM.

Conclusion

Diversification of rice-wheat system as rice-yellow sarson-groundnut and rice-vegetable pea-maize results in better growth of the crop which thereby increases the yield. Residue management's techniques where the organics are used to increase the rate of decomposition of the residue by lowering the C: N ratio also results in higher yield that other. 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 growth and yield.

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