Growth analysis, NPK uptake and Crude Protein Content in diversified Cropping System under Natural Farming

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ABSTRACT

A field experiment was conducted during *rabi* 2020-21 to *kharif* 2021 at Research Farm, Agronomy, CSKHPKV, Palampur (H.P.) to study growth analysis, NPK uptake and crude protein content in diversified cropping system under natural farming. The experiment was consisted of 9 treatments (C_1 -Maize - wheat, C_2-Black gram - wheat + gram, C_3-Soybean - wheat + lentil, C_4-Cowpea - wheat + sarson, C_5-Okra - wheat + pea, C_6-Maize + black gram - gram, C_7-Maize + soybean - lentil, C_8-Maize + cowpea - sarson and C_9-Maize + okra - pea), replicated three time in Randomized Block Design. Legume-based systems resulted in significantly higher CGR and RGR among the cropping systems. During *rabi* 2020-21, the highest CGR was observed in the C_3 (soybean - wheat + lentil) of 5.53 g m^{-2} day^{-1}, followed by C_1 (maize - wheat) at 5.29 g m^{-2} day^{-1}. In kharif 2021, C_4 (cowpea - wheat + sarson) showed the highest CGR (10.22 g m^{-2} day^{-1}). Higher RGR was found in C_7 system (maize + soybean - lentil) at 8.89 mg g^{-1} day^{-1}, in *rabi* 2020-21. While, the system C_2 (black gram - wheat + gram) resulted in higher RGR at 13.76 mg g^{-1} day^{-1} before harvest in *kharif* 2021. Legumes enhances nutrient uptake by improving soil fertility and also resulted in improved the dry matter accumulation during mid-to-late crop stages under natural farming. A significant variation was observed higher nutrient uptake in both seed and by-products with legume-based systems under natural farming. Enhanced crude protein content was found in the legume-based systems, such as C_8 (maize + cowpea - sarson) with 75.50 % in *rabi* 2020-21.

Key words: Natural farming, cropping system, crop growth rate, relative growth rate, NPK uptake, crude protein content

INTRODUCTION

In 1960's the Green Revolution started, which led to use of chemical pesticides, fertilizers, and high yielding varieties, resulted in increased agricultural productivity. Although it addressed food security, extensive long-term use of chemicals resulted in water pollution, reduction in biodiversity and soil degradation (Pingali 2012). Introduction of the natural farming in the recent decades which prioritize environmentally friendly, chemical-free techniques. The methods which are used in Natural Farming like Crop rotation, green manure, and animal integration to preserve soil fertility and manage pests. Also known as Subhash Palekar Natural Farming (SPNF), no use of artificial/synthetic chemicals, inputs the inputs used in natural farming results in improving soil health, by utilizing locally available resources like jeevamrit (a microbially rich biofertilizer) (Palekar 2016). In short, compared to conventional farming, the natural farming, reduces the environmental impact of agriculture, while enhancing soil organic matter and biodiversity. Natural farming is becoming more and more known as sustainable method of farming, as health concerns about chemical residues in food and the environment progress under conventional farming Devarinti (2016).

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MATERIALS AND METHODS

A field experiment was carried out during *rabi* 2020-21 to *kharif* 2021 at the research farm, Department of Agronomy, CSK HPKV, Palampur, Kangra, Himachal Pradesh.

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The experiment was carried out in Randomised Block Design with three replication and nine cropping system. The soil type that was silty-clay loam had low amounts of potassium and nitrogen, moderate levels of phosphorus, and an acidic content. The treatments comprised of C_1 -Maize - wheat, C_2-Black gram - wheat + gram, C_3-Soybean - wheat + lentil, C_4-Cowpea - wheat + sarson, C_5-Okra - wheat + pea, C_6-Maize + black gram - gram, C_7-Maize + soybean - lentil, C_8-Maize + cowpea - sarson and C_9-Maize + okra – pea. In the *rabi* season the crops was sown in replacement series in intercropping system, while in *kharif* the additive series.

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Crop Growth Rate (g m^{-2} day^{-1})

Crop growth rate (CGR) expresses the gain in dry matter production of the crop per unit land area per unit time and is expressed as gram per meter square per day (g m^{-2} day^{-1}). It is calculated according to the formula given by Watson (1952).

$$CGR = \frac{1}{P} \times \frac{W_2 - W_1}{T_2 - T_1}$$

Where, W_2 and W_1 are dry weights at two sampling times T_2 and T_1 respectively.

Relative Growth Rate (mg g^{-1} day^{-1})

The relative growth rate (RGR) represents the rate of increase in dry weight per unit of plant dry weight and is expressed as mg m^{-2} day^{-1} (Blackman 1919).

$$RGR = \frac{\ln W_2 - \ln W_1}{t_2 - t_1}$$

NPK Uptake (kg ha^{-1})

After the harvesting, the plant sample and seeds both were dried and converted to fine powder by using grinder total N, P and K were determined. Total N modified kjeldahl method (Jackson 1967); total phosphorus by using vanado-molybdate phosphoric acid yellow colour method (Jackson 1967) and total potassium diacid digestion method (Black 1965). Nutrient uptake is calculated by multiplying the nutrient concentration by the dry matter content and dividing by 100.

$$\text{Nutrient uptake (Kg } ha^{-1}) = \frac{\text{nutrient concentration (\%)} \times \text{dry matter content (kg } ha^{-1})}{100}$$

Crude Protein

By multiplying the N content of grains by a factor of 6.25, the crude protein of grains was determined (Jones 1941).

Results and discussion

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Crop Growth Rate (g m^{-2} day^{-1})

The variation in Crop Growth Rate (CGR) was observed in the cropping system after sowing to till harvest during *rabi* 2020-21 and *kharif* 2021 (Fig.1 and Fig. 2). At 30 DAS the CGR, in the cropping system ranging from 0.15 g m^{-2} day^{-1} in C_6 (maize + black gram - gram) to 2.46 g m^{-2} day^{-1} in C_8 (maize + cowpea - sarson) system in *rabi* 2020-21. At 120-150 DAS the CGR ranges between 0.39 g m^{-2} day^{-1} in C_6 (maize + black gram – gram) to 5.53 g m^{-2} day^{-1} in C_3 (soybean - wheat + lentil) system. The highest CGR was observed in C_3 (soybean - wheat + lentil) system with

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5.53 g m^{-2} day^{-1}, followed by the C_1 (maize – wheat) system at 5.29 g m^{-2} day^{-1}. Lowest CGR was observed in C_6 (maize + black gram - gram) system at 0.39 g m^{-2} day^{-1}. Among intercrops at 120-150 DAS, the highest CGR was observed in C_3 (soybean - wheat + lentil) system with 1.77 g m^{-2} day^{-1}, followed by the C_5 (okra - wheat + pea) at 1.70 g m^{-2} day^{-1}. Lowest CGR was observed in C_2 (black gram - wheat + gram) system at 0.41 g m^{-2} day^{-1}. In subsequent, *kharif* 2021, initially at 30 DAS, CGR among the cropping system ranging from 0.09 g m^{-2} day^{-1} in C_2 (black gram - wheat + gram) to 1.82 g m^{-2} day^{-1} in C_7 (maize + soybean - lentil) system. At 60-90 DAS the CGR ranges between 0.56 g m^{-2} day^{-1} in C_2 (black gram - wheat + gram) to 10.22 g m^{-2} day^{-1} in C_4 (cowpea - wheat + sarson). The highest CGR was observed in C_4 (cowpea - wheat + sarson) system with 10.22 g m^{-2} day^{-1}, followed by the C_5 (okra - wheat + pea) at 3.57 g m^{-2} day^{-1}. Lowest CGR was observed in C_2 (black gram - wheat + gram) system at 0.56 g m^{-2} day^{-1}. Among intercrops at 60-90 DAS, the highest CGR was observed in C_8 (maize + cowpea - sarson) system with 10.18 g m^{-2} day^{-1}, followed by the C_9 (maize + okra - pea) at 3.77 g m^{-2} day^{-1}. The lowest CGR was observed in C_6 (maize + black gram - gram) at 0.49 g m^{-2} day^{-1}. In the wheat - legume rotation, the CGR resulted in higher than in monocropping or continuous maize - wheat systems, during vegetative stage till harvest of crop growth (Choruma et al., 2022; Jensen et al., 2012). The legume-based rotations enhance CGR; also contribute carbon sequestration and enhanced nutrient cycling (Dwivedi et al., 2015; Kirkegaard and Ryan, 2014).

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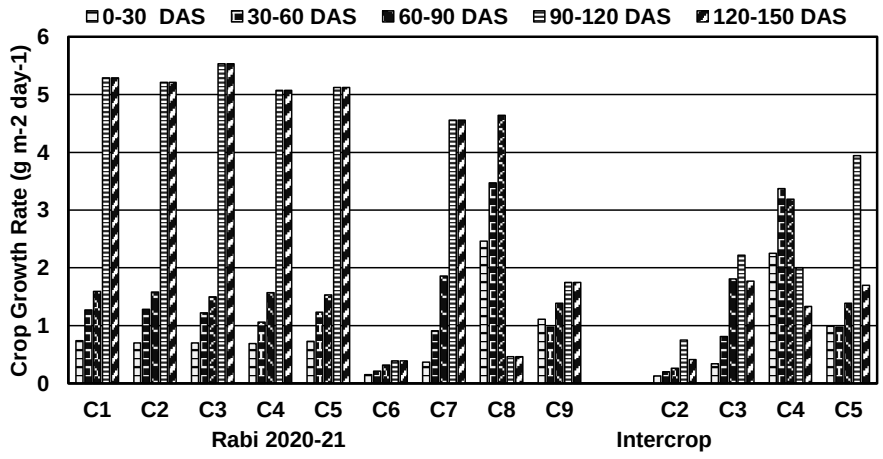

Fig.1 Effect of cropping system on crop growth rate (g m^{-2} day^{-1}) under natural farming during *rabi* 2020-21

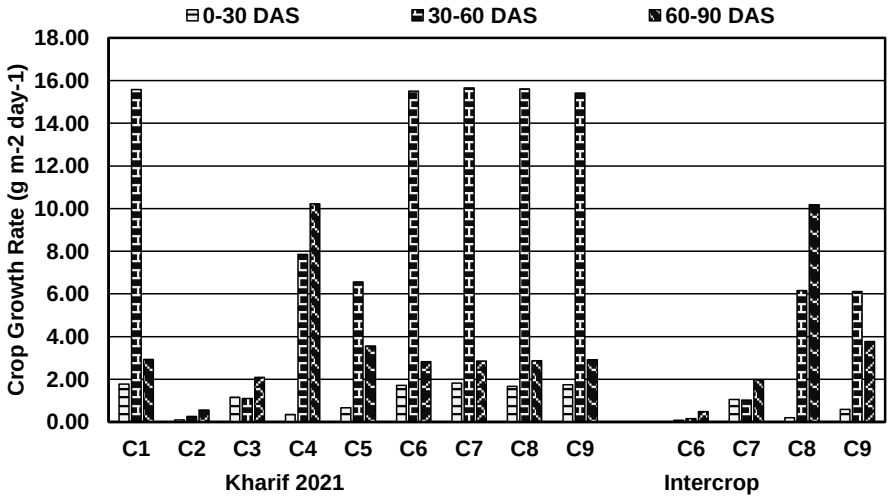

Fig.2 Effect of cropping system on crop growth rate (g m^{-2} day^{-1}) under natural farming during *kharif* 2020-21

Relative Growth Rate (mg g^{-1} day^{-1})

The Relative Growth Rate (RGR) was observed in the cropping system after sowing to till harvest during *rabi* 2020-21 and *kharif* 2021 (Fig. 3 and Fig. 4). Initially at 30 DAS the RGR ranges from 9.06 mg g^{-1} day^{-1} in C_9 (maize + okra - pea) to 18.02 mg g^{-1} day^{-1} in C_7 (maize + soybean - lentil) system in *rabi* 2020-21. At 120-150 DAS the RGR ranges between 0.50 mg g^{-1} day^{-1} in C_8 (maize + cowpea - sarson) to 8.89 mg g^{-1} day^{-1} in C_7 (maize + soybean - lentil) system. The highest RGR was observed in C_7 (maize + soybean - lentil) system with 8.89 mg g^{-1} day^{-1}, followed by the C_3 (soybean - wheat + lentil) system at 6.80 mg g^{-1} day^{-1}. Lowest RGR was observed in C_8 (maize + cowpea - sarson) system at 0.50 mg g^{-1} day^{-1}. Among intercrops at 120-150 DAS, the highest RGR was observed in C_3 (soybean - wheat + lentil) system with 4.26 mg g^{-1} day^{-1}, followed by the C_2 (black gram - wheat + gram) at 3.85 mg g^{-1} day^{-1}. Lowest RGR was observed in C_4 (cowpea - wheat + sarson) system at 1.69 mg g^{-1} day^{-1}. In subsequent, *kharif* 2021, initially at 30 DAS, RGR among the cropping system ranging from 9.71 mg g^{-1} day^{-1} in C_3 (soybean - wheat + lentil) to 45.83 mg g^{-1} day^{-1} in C_4 (cowpea - wheat + sarson) system. At 60-90 DAS the RGR ranges between 2.19 mg g^{-1} day^{-1} in C_7 (maize + soybean - lentil) to 13.76 mg g^{-1} day^{-1} in C_2 (black gram - wheat + gram). The highest RGR was observed in C_2 (black gram - wheat + gram) system with 13.76 mg g^{-1} day^{-1}, followed by the C_4 (cowpea - wheat + sarson) at 11.72 mg g^{-1} day^{-1}. Lowest RGR was observed in C_7 (maize + soybean - lentil) system at 2.19 mg g^{-1} day^{-1}. Among intercrops at 60-90 DAS, the highest RGR was observed C_6 (maize + black gram - gram) system with 16.61 mg g^{-1} day^{-1}, followed by the C_8 (maize + cowpea - sarson) at 13.84 mg g^{-1} day^{-1}. Lowest RGR was observed in C_9 (maize + okra - pea) system at 6.46 mg g^{-1} day^{-1}. Dwivedi et al. (2015) reported that the maize-legume intercropping systems led to significant improvements in RGR; also, systems increased overall biomass production due to enhanced nutrient availability from legumes. The inclusion of legumes resulted in

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improved nutrient status also enhanced growth rates (Jensen et al. 2012). Crop rotation with legumes enhances growth rates and yield in multiple cropping system (Kirkegaard and Ryan 2014). In wheat and maize system, addition of legumes resulted in higher RGR by improving soil health and nutrient availability (Choruma et al. 2022).

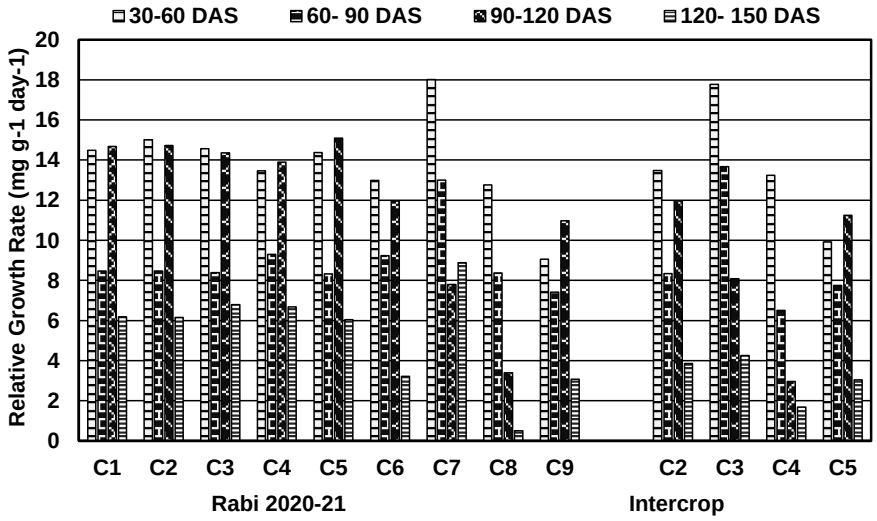

Fig.3 Effect of cropping system on relative growth rate (mg g^{-1} day^{-1}) under natural farming during *rabi* 2020-21

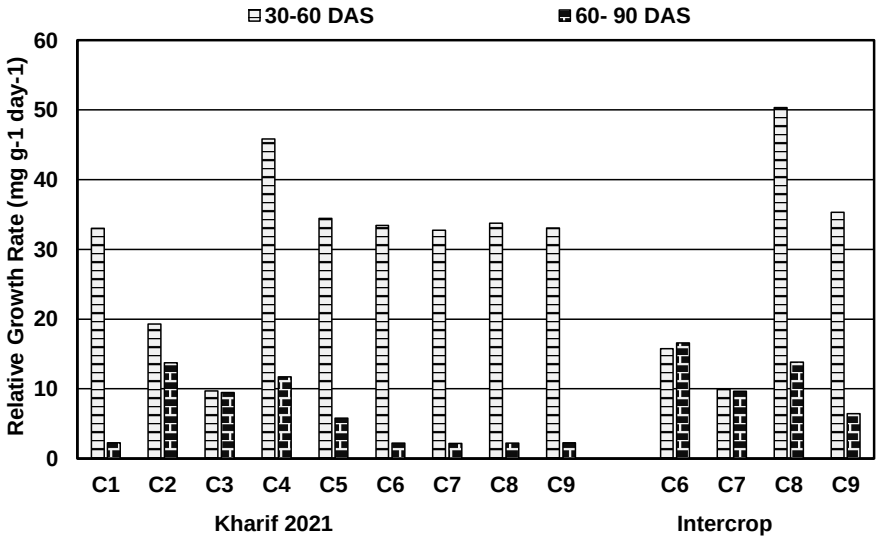

Fig.4 Effect of cropping system on relative growth rate (mg g^{-1} day^{-1}) under natural farming during *kharif* 2021

NPK Uptake (kg ha^{-1})

The data for NPK uptake in the seed and by-product for *rabi* 2020-21 and *kharif* 2021 presented in the Fig. 5, Fig.6 and Fig.7. A variation for the NPK uptake in seed and by-product was observed during both the crop season under natural farming.

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N Uptake (seed and by-product)

In the *rabi* 2020-21, the highest seed N uptake was observed in the C_9 (maize + okra - pea) system at 67.52 kg ha^{-1}, followed by C_7 (maize + soybean - lentil) at 64.92 kg ha^{-1}. The Lowest seed N uptake was observed in the C_1 (maize – wheat) system with 30.96 kg ha^{-1}. In subsequent *kharif* 2021, the highest seed N uptake was observed in the C_5 (okra - wheat + pea) system at 56.84 kg ha^{-1}, followed by C_9 (maize + okra - pea) at 53.00 kg ha^{-1}. The lowest seed N uptake was observed in the C_2 (black gram - wheat + gram) system with 24.26 kg ha^{-1}. Overall system's, the highest seed N uptake was observed in the C_9 (maize + okra - pea) system at 120.52 kg ha^{-1}, followed by C_5 (okra - wheat + pea) at 107.69 kg ha^{-1}. The Lowest seed N uptake was observed in the C_2 (black gram - wheat + gram) system with 57.66 kg ha^{-1}. In the *rabi* 2020-21, the highest by-product N uptake was observed in the C_7 (maize + soybean - lentil) system at 18.43 kg ha^{-1}, followed by C_8 (maize + cowpea - sarson) at 16.14 kg ha^{-1}. The Lowest by-product N uptake was observed in the C_9 (maize + okra - pea) system with 6.66 kg ha^{-1}. In subsequent *kharif* 2021, the highest by-product N uptake was observed in the C_2 (black gram - wheat + gram) system at 34.10 kg ha^{-1}, followed by C_8 (maize + cowpea - sarson) at 28.33 kg ha^{-1}. The lowest by-product N uptake was observed in the C_5 (okra - wheat + pea) system with 3.50 kg ha^{-1}. Overall system's, the highest by-product N uptake was observed in the C_4 (cowpea - wheat + sarson) system at 50.43 kg ha^{-1}, followed by C_2 (black gram - wheat + gram) at 46.85 kg ha^{-1}. The Lowest by-product N uptake was observed in the C_5 (okra - wheat + pea) system with 11.55 kg ha^{-1}.

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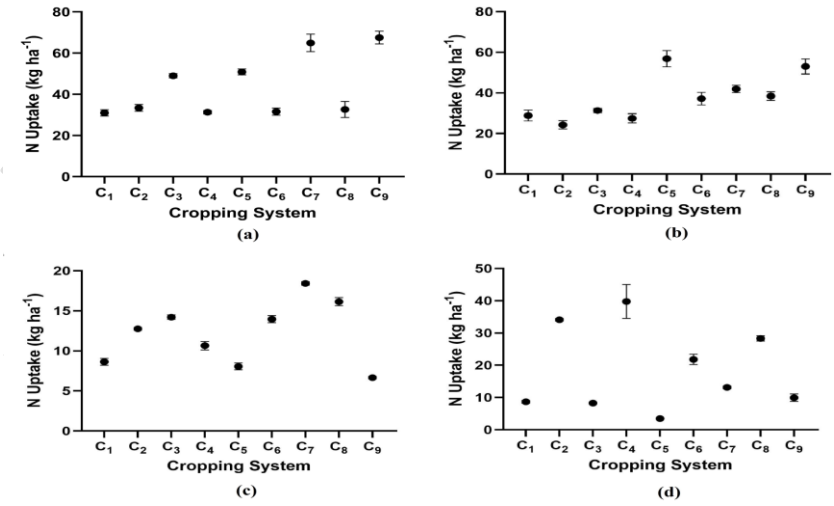

Fig.5 (a) N uptake in seed during *rabi* 2020-21, (b) N uptake in seed during *kharif* 2021, (c) N uptake in straw during *rabi* 2020-21 and (d) N uptake in straw during *kharif* 2021

Adu-Gyamfi et al. (2007) observed higher nitrogen uptake under soybean-maize intercropping systems compared to monocropping system. Rao and Mathuva (2000) found significantly higher nitrogen accumulation in the cowpea and subsequent cereal crop under cowpea - maize intercropping system. In lentil-based intercropping with cereals like wheat and barley resulted in improved in N uptake due to biological nitrogen fixation by lentils and cowpea (Stagnari et al. 2017; Sharma T et al. 2023). Rotation with legumes such as soybeans under wheat-based system resulted in enhanced nitrogen content in both the seed and straw of subsequent cereal crops due to residual nitrogen from the legumes (Peoples et al.1995)

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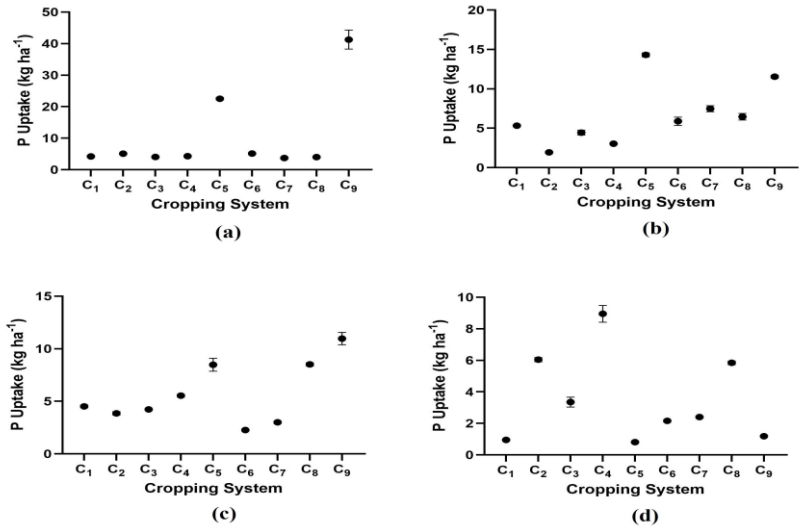

Fig.6 (a) P uptake in seed during *rabi* 2020-21, (b) P uptake in seed during *kharif* 2021, (c) P uptake in straw during *rabi* 2020-21 and (d) P uptake in straw during *kharif* 2021

P Uptake (seed and by-product)

In the *rabi* 2020-21, the highest seed P uptake was observed in the system C_9 (maize + okra - pea) at 41.29 kg ha^{-1}, followed by C_5 (okra - wheat + pea) at 22.54 kg ha^{-1}. The Lowest seed P uptake was observed in the system C_7 (maize + soybean - lentil) with 3.74 kg ha^{-1}. In subsequent *kharif* 2021, the highest seed P uptake was observed in the C_5 (okra - wheat + pea) system at 14.30 kg ha^{-1}, followed by C_9 (maize + okra - pea) at 11.54 kg ha^{-1}. The lowest seed P uptake was observed in the C_2 (black gram - wheat + gram) system with 1.94 kg ha^{-1}. Overall system's, the highest seed P uptake was observed in the C_9 (maize + okra - pea) system at 52.83 kg ha^{-1}, followed by C_5 (okra - wheat + pea) at 36.84 kg ha^{-1}. The Lowest seed P uptake was observed in the C_2 (black gram - wheat + gram) system with 7.06 kg ha^{-1}. In the *rabi* 2020-21,

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The highest by-product P uptake was observed in the system C_9 (maize + okra - pea) at 10.97 kg ha^{-1}, followed by C_8 (maize + cowpea - sarson) at 8.51 kg ha^{-1}. The Lowest by-product P uptake was observed in the system C_6 (maize + black gram - gram) with 2.27 kg ha^{-1}. In subsequent *kharif* 2021, the highest by-product P uptake was observed in the C_2 (black gram - wheat + gram) system at 6.05 kg ha^{-1}, followed by C_8 (maize + cowpea - sarson) at 5.85 kg ha^{-1}. The lowest by-product P uptake was observed in the C_5 (okra - wheat + pea) system with 0.81 kg ha^{-1}. Overall system's, the highest by-product P uptake was observed in the C_4 (cowpea - wheat + sarson) system at 14.49 kg ha^{-1}, followed by C_8 (maize + cowpea - sarson) at 14.36 kg ha^{-1}. The Lowest by-product P uptake was observed in the C_6 (maize + black gram - gram) system with 4.43 kg ha^{-1}. Singh et al. (2015) reported that in intercropping with legumes resulted in enhanced phosphorus uptake compared to monocropping. (Naseem et al. 2020) reported that significantly enhanced phosphorus use efficiency, resulting in higher seed and biomass phosphorus uptake, when maize intercropped legumes. The leguminous crops resulted in crucial role in the phosphorus cycling and uptake due to their symbiotic relationships with mycorrhizal fungi (Dutta et al. 2016).

K Uptake (seed and by-product)

In the *rabi* 2020-21, the highest seed K uptake was observed in the C_9 (maize + okra - pea) system at 45.71 kg ha^{-1}, followed by C_5 (okra - wheat + pea) at 3.32 kg ha^{-1}. The Lowest seed K uptake was observed in the C_7 (maize + soybean - lentil) system with 3.34 kg ha^{-1}. In subsequent *kharif* 2021, the highest seed K uptake was observed in the C_5 (okra - wheat + pea) system at 24.52 kg ha^{-1}, followed by C_9 (maize + okra - pea) at 16.63 kg ha^{-1}. The lowest seed K uptake was observed in the C_2 (black gram - wheat + gram) system with 4.68 kg ha^{-1}. Overall system's, the highest seed K uptake was observed in the C_9 (maize + okra - pea) system at 31.21 kg ha^{-1}, followed by C_5 (okra - wheat + pea) at 24.84 kg ha^{-1}. The Lowest seed K uptake was observed in the C_2 (black gram - wheat + gram) system with 5.84 kg ha^{-1}. In the *rabi* 2020-21, the highest by-product K uptake was observed in the C_1 (maize – wheat) system at 28.77 kg ha^{-1}, followed by C_2 (black gram - wheat + gram) at 28.16 kg ha^{-1}. The Lowest by-product K uptake was observed in the C_9 (maize + okra - pea) system with 7.52 kg ha^{-1}.

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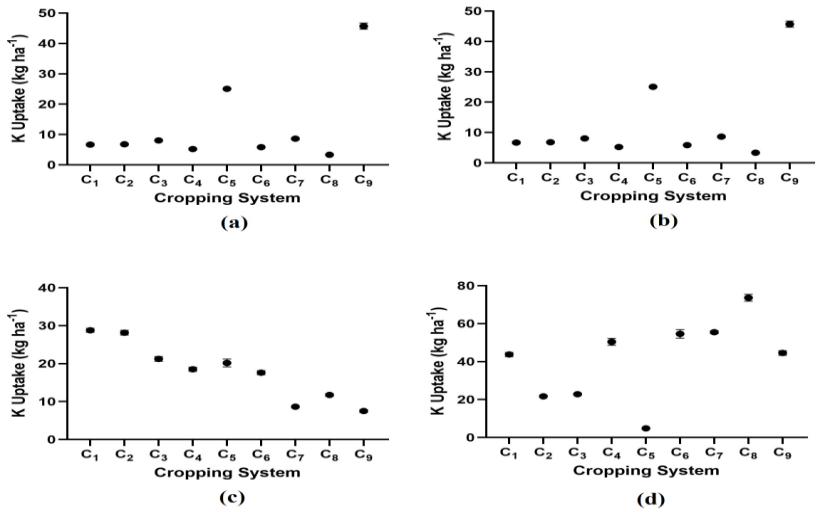

Fig.7 (a) K uptake in seed during *rabi* 2020-21, (b) (f) K uptake in seed during *kharif* 2021, (c) K uptake in straw during *rabi* 2020-21 and (d) K uptake in straw during *kharif* 2021

In subsequent *kharif* 2021, the highest by-product K uptake was observed in the C_8 (maize + cowpea - sarson) system at 73.63 kg ha^{-1}, followed by C_7 (maize + soybean - lentil) at 55.49 kg ha^{-1}. The lowest by-product K uptake was observed in the C_5 (okra - wheat + pea) system with 4.86 kg ha^{-1}. Overall system's, the highest by-product K uptake was observed in the C_8 (maize + cowpea - sarson) system at 85.38 kg ha^{-1}, followed by C_1 (maize – wheat) at 72.52 kg ha^{-1}. The Lowest by-product K uptake was observed in the C_5 (okra - wheat + pea) system with 25.03 kg ha^{-1}. The combination of legumes and cereals resulted in enhanced K uptake compared to sole cropping, overall increased yields and nutrient content (Ghosh and Hossain 2019). Overall improved nutrient profile in intercropping legumes with cereals, including potassium uptake, particularly in systems like maize-legume intercropping (Adu-Gyamfiet al. 2007).

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Crude Protein

Crude protein content for the cropping system in *rabi* 2020-21 and *kharif* 2021, presented in the Table 1. In *rabi* 2020-21, the highest crude protein was found in the C_8 (maize + cowpea - sarson) system at 75.50 %, followed by C_6 (maize + black gram - gram) at 71.48 %. The lowest crude protein was found in the C_4 (cowpea - wheat + sarson) with 8.58 %. The crude protein among the intercrops was found in the order C_4 (cowpea - wheat + sarson) > C_2 (black gram - wheat + gram) > C_3 (soybean - wheat + lentil) > C_5 (okra - wheat + pea). In *rabi* 2020-21, the highest crude protein was found in C_2 (black gram - wheat + gram) system at 22.63 %, followed by C_3 (soybean - wheat + lentil) at 18.06 %. The lowest crude protein was found in the C_1 (maize – wheat) with 7.46 %. The crude protein among the intercrops was found in the order C_6 (maize + black gram - gram) > C_7 (maize + soybean - lentil) > C_8 (maize + cowpea - sarson) > C_9 (maize + okra - pea). The legumes significantly enhanced the crude protein content of the main crops due to their

nitrogen-fixing ability (Ghosh et al. 2019). Ali et al. (2017) observed that intercropping legumes with cereals improved protein content in both crops compared to sole. The addition of legumes as intercrop (*viz*. black gram and cowpea) resulted in increased crude protein content in main crops (Sahni et al. 2021). Legume as an intercrop improves main crops nutritional quality especially the crude protein content (Choudhary et al. 2020).

Table 1. Effect of cropping systems on crude protein in grains during crop season 2020-21 under natural farming

Cropping system	Crude Protein			
	***Rabi* 2020-21**	**Intercrop**	***Kharif* 2021**	**Intercrop**
C_1 Maize - wheat	8.69	-	7.46	-
C_2 Black gram - wheat + gram	8.75	66.81	22.63	-
C_3 Soybean - wheat + lentil	8.75	50.75	18.06	-
C_4 Cowpea - wheat + sarson	8.58	75.06	13.81	-
C_5 Okra - wheat + pea	8.88	10.06	6.96	-
C_6 Maize + black gram - gram	71.48	-	7.73	20.13
C_7 Maize + soybean - lentil	52.13	-	7.69	16.00
C_8 Maize + cowpea - sarson	78.50	-	7.79	13.13
C_9 Maize + okra - pea	10.33	-	8.31	5.81

Conclusion

The study evaluated Crop Growth Rate (CGR), Relative Growth Rate (RGR), NPK uptake and crude protein content across various cropping systems during *rabi* 2020-21 and *kharif* 2021. It was found that the significant variations in CGR and RGR among systems, with legume-based systems (e.g., C_3: soybean - wheat + lentil and C_8: maize + cowpea - sarson). At 120-150 DAS, the highest CGR (5.53 g m^{-2} day^{-1}) was observed in the C_3 (soybean - wheat + lentil) system, while C_4 (cowpea - wheat + sarson) and C8 systems showed superior performance in subsequent *kharif* 2021. Similarly, the inclusion legume in cropping system resulted in higher RGR, with C_7 (maize + soybean - lentil) and C_3 (soybean - wheat + lentil) system maximum rates at later stages. Enhanced NPK uptake in seeds and by-products was found significantly higher in legume-based cropping system compared to C_1 (maize – wheat) system under natural farming. The crude protein content was also found to be higher in legume-based systems (*viz*. C_8 and C_2) under natural farming. In addition, legume-based systems not only improve soil fertility, but also resulted in increase in dry matter accumulation, enhanced nutrient uptake and crude protein content among the cropping system under natural farming.

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DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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