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Growth, NPK Uptake and Crude Protein Content in Diversified Cropping System under Natural Farming

Mohit Naik [a], Maan Chand Rana [a], Narender Kumar Sankhyan [b], Sahil Chauhan [c], Raghuveer Choudhary [d] and Bharat Bhushan Rana [a*]

[a] Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, H.P.- 176 062, India.
[b] Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, H.P.- 176 062, India.
[c] Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara, Pb. -144411, India.
[d] Department of Agronomy, College of Agriculture, Junagarh Agricultural University, Junagarh, Gujarat – 362001, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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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

**Corresponding author: E-mail: bharatbhushan5500@gmail.com;*

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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. The natural farming inputs includes *beejamrit* (used for seed treatment @ 1 litre/10 kg seed), *jeevamrit* (5 drenching application at 21 days interval; total used 450 litres), *ghanjeevamrit* (soil applied during sowing @ 500 kg ha^{-1}) and mulching (applied after germination @ 10000 kg ha^{-1}). 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.

Keywords: Crop growth rate; cropping system; crude protein content; natural farming; NPK uptake; relative growth rate.

1. 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). For sustainable agriculture, it is important to conserve natural resources by reducing degradation and dependency on synthetic chemicals used as fertilizers, pest control, and weed management. The inclusion of legumes, vegetables, and other crops in the existing non-leguminous systems enhances overall production and profitability. Also, inclusion of legumes in the cropping system as intercrop/sole crop resulted in soil health by enhancing soil fertility, increasing organic matter and nutrient cycling, results in sustainable and productive agricultural systems [1]. 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) [2]. In short, compared to conventional farming, the natural farming, reduces the environmental impact of agriculture, while enhancing soil organic matter and biodiversity. Natural farming principles advocate that the growing of two or more than two crops in a year result in reduced pest attacks, optimizes land use and maintain ecological balance, without affecting the soil resources. 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 [3].

2. 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. 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. The initial status of the before the start of the experiment presented in the Table 1. The natural farming inputs includes *beejamrit* (used for seed treatment @ 1 litre/10 kg seed), *jeevamrit* (5 drenching application at 21 days interval; total used 450 litres), *ghanjeevamrit* (soil applied during sowing @ 500 kg ha^{-1}) and mulching (applied after germination @ 10000 kg ha^{-1}). The details of the varieties used, seed rates and row spacing presented in the Table 2.

2.1 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 [11].

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

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

2.2 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} [12].

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

2.3 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 [13] total phosphorus by using vanado-molybdate phosphoric acid yellow colour method [13] and total potassium diacid digestion method [14]. Nutrient uptake is calculated by multiplying the nutrient concentration by the dry matter content and dividing by 100.

> Nutrient uptake (Kg ha-1)= nutrient concentration (%) × dry matter content (kg ha -1) / 100

2.4 Crude Protein

By multiplying the N content of grains by a factor of 6.25, the crude protein of grains was determined [15].

3. RESULTS AND DISCUSSION

3.1 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 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}. Among the systems intercrop like Lentil, cowpea resulted in higher N fixation compared to other legumes; also, the decomposition of the mulching provides the sufficient nutrients in the soil, resulted in enhanced dry matter accumulation. The application of Jeevamrit enhances soil microbial activity, leading to enhanced decomposition of ghanjeevamrit and mulching improves soil moisture, resulted in higher dry matter accumulation among the intercrop (Prasad and Srivastava 2019; Saharan et al. [16] Similarly, Abdel-Wahab et al. [17] and Manhas et al. [18] found that 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.

3.2 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

Table 1. Initial soil physical, chemical and biological parameters of the experimental site

Particulars		Content in soil	Analytical method employed
A. Physical properties			
i.	Sand (%)	20.5	International pipette method [4].
ii.	Silt (%)	43.6	
iii.	Clay (%)	35.7	
iv.	Texture	Silty clay loam	
v.	Bulk density (g cm^{-3})	1.33	Core sampler method [5].
B. Chemical properties			
i.	pH	5.01	Glass electrode pH meter [6]
ii.	Electrical Conductivity (EC) (µS m^{-1})	110.01	Suspension with EC meter [6]
iii.	Organic carbon (%)	0.72	Wet digestion method [7].
iv.	Available nutrient (kg ha^{-1})		
a.	Available nitrogen	258.45	Alkaline permanganate method [8]
b.	Available phosphorus	24.89	Ammonium molybdate blue colour method [9]
c.	Available potassium	167.46	Ammonium acetate extraction method [10]

Table 2. Details of the varieties used, seed rates and row spacing

Crop	Variety	Seed rate (kg ha^{-1})	Spacing (cm)
Rabi			
Wheat	HPW-368	100	22.5
Gram	Him-Chana 1	45	25
Lentil	HPLO-1	30	25
Pea	PB-89	75	45 x 10
Sarson	Sheetal	6	30
Kharif			
Maize	Girija	20	60 x 20
Soybean	HIMCO-1685	75	45 x 10
Black Gram	Him Mash 1	20	30
Cowpea	CO-519	20	45
Okra	P8	20	45 x 15

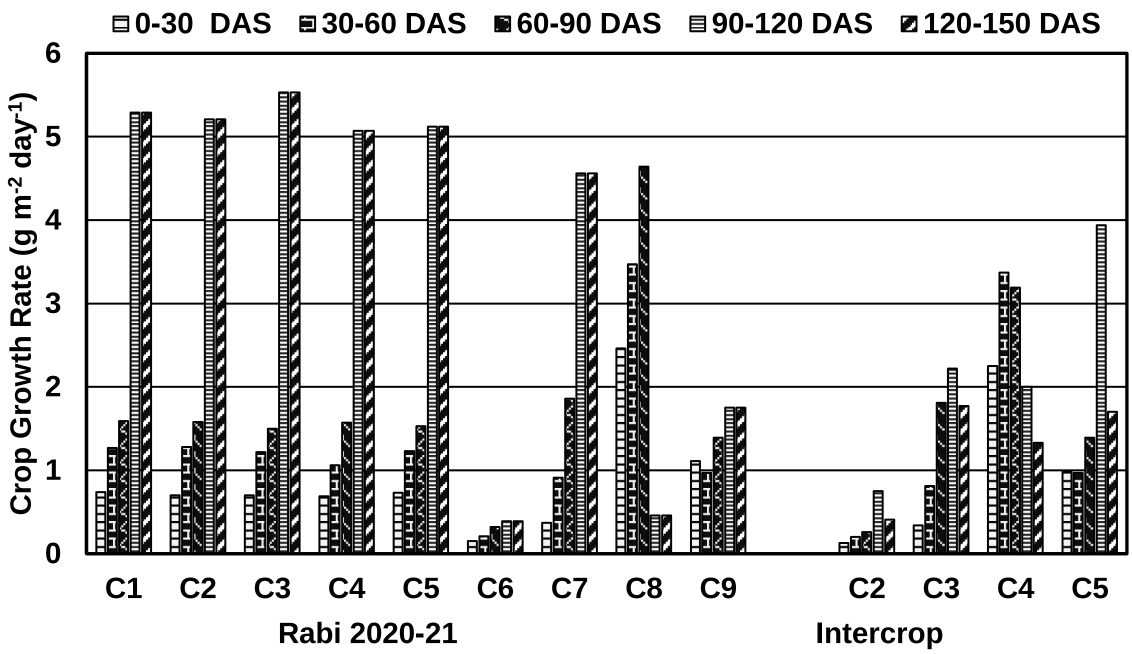

Fig. 1. Effect of cropping system on crop growth rate (g m^{-2} day^{-1}) under natural farming during *Rabi* 2020-21

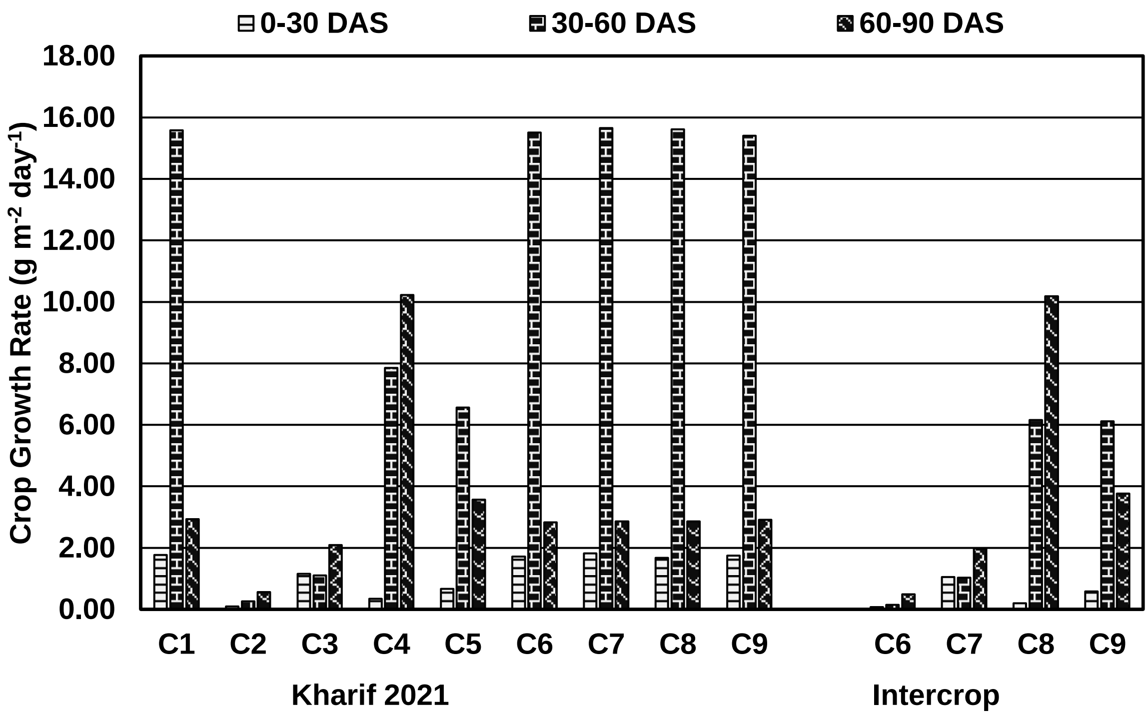

Fig. 2. Effect of cropping system on crop growth rate (g m^{-2} day^{-1}) under natural farming during *Kharif* 2020-21

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}. This can be attributed to improved soil physio-chemical and biological properties by the application of jeevamrit, ghanjeevamrit and mulching with legume-based system. The inclusion of legumes resulted in improved nutrient status also enhanced dry matter accumulation improved CGR and RGR [18]. In wheat and maize system, addition of legumes resulted in higher RGR by improving soil health and nutrient availability [17].

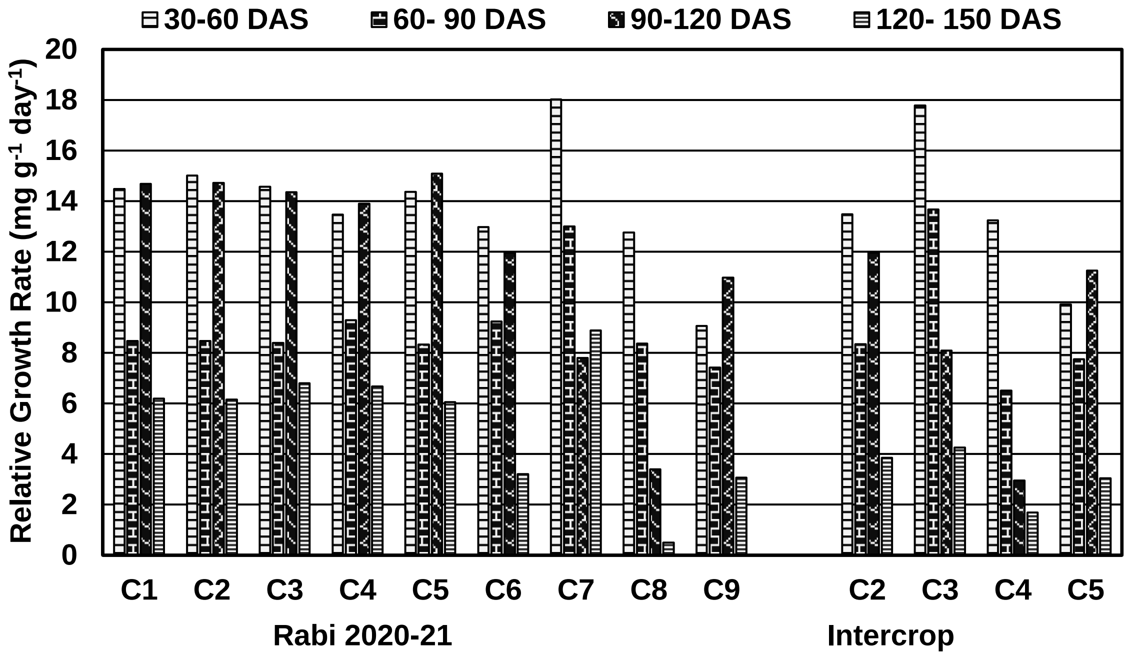

Fig. 3. Effect of cropping system on relative growth rate (mg g^{-1} day^{-1}) under natural farming during *Rabi* 2020-21

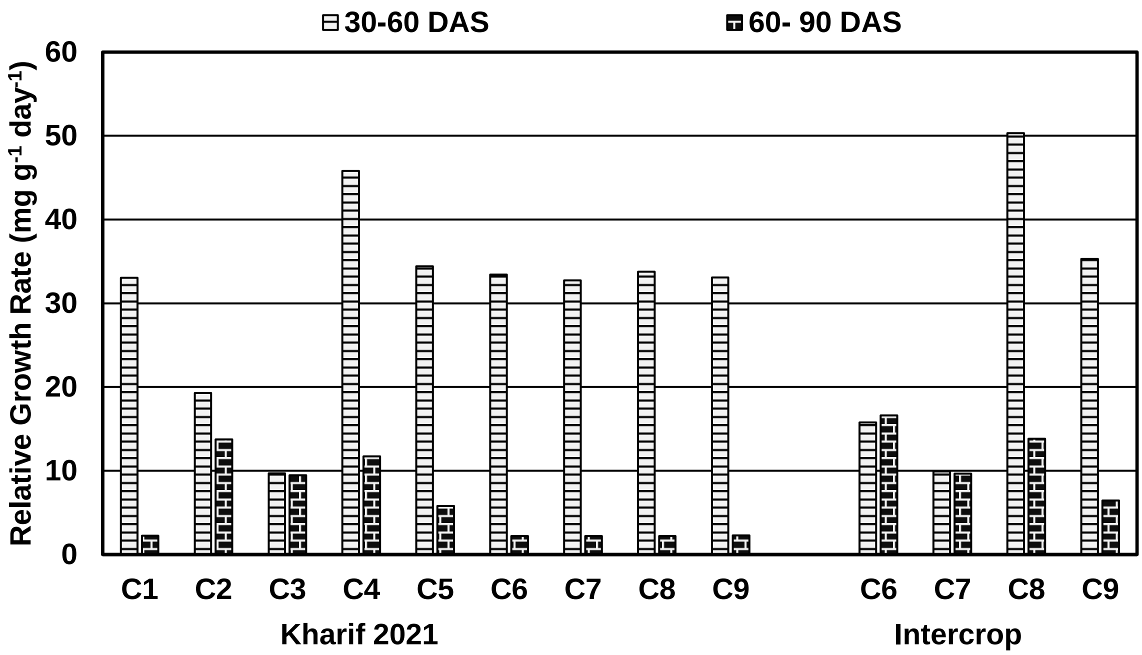

Fig. 4. Effect of cropping system on relative growth rate (mg g^{-1} day^{-1}) under natural farming during *Kharif* 2021

3.3 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.

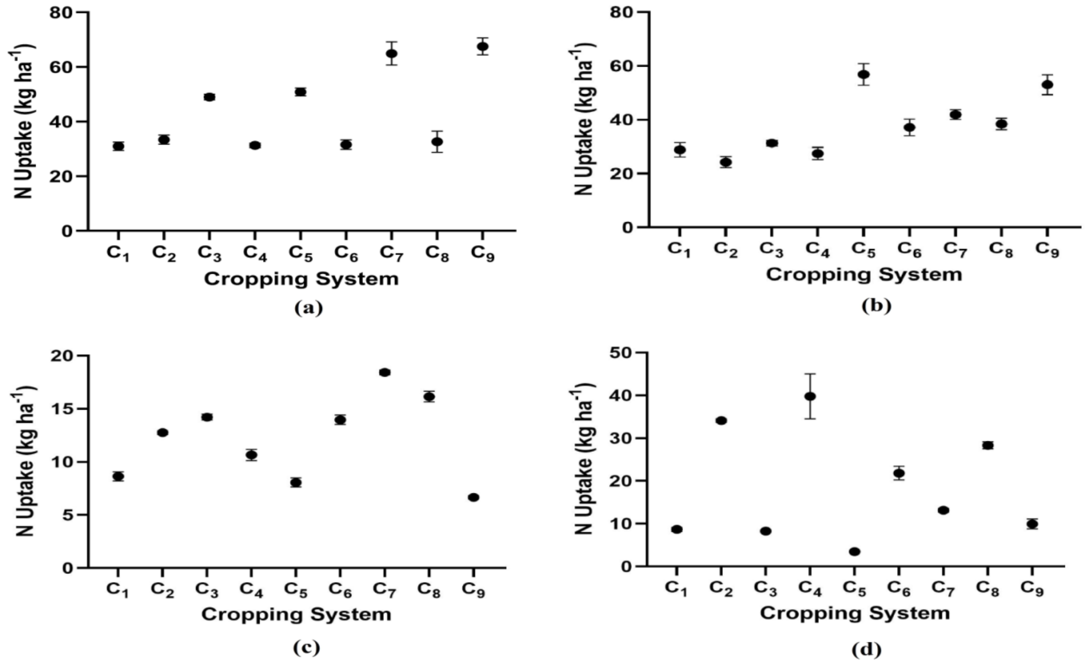

Fig. 5. (a) N uptake in seed during *Rabi* 2020-21, (b) N uptake in seed during *Kharif* 2021, (c) N uptake in straw during *Rabi* 2020-21 and (d) N uptake in straw during *Kharif* 2021

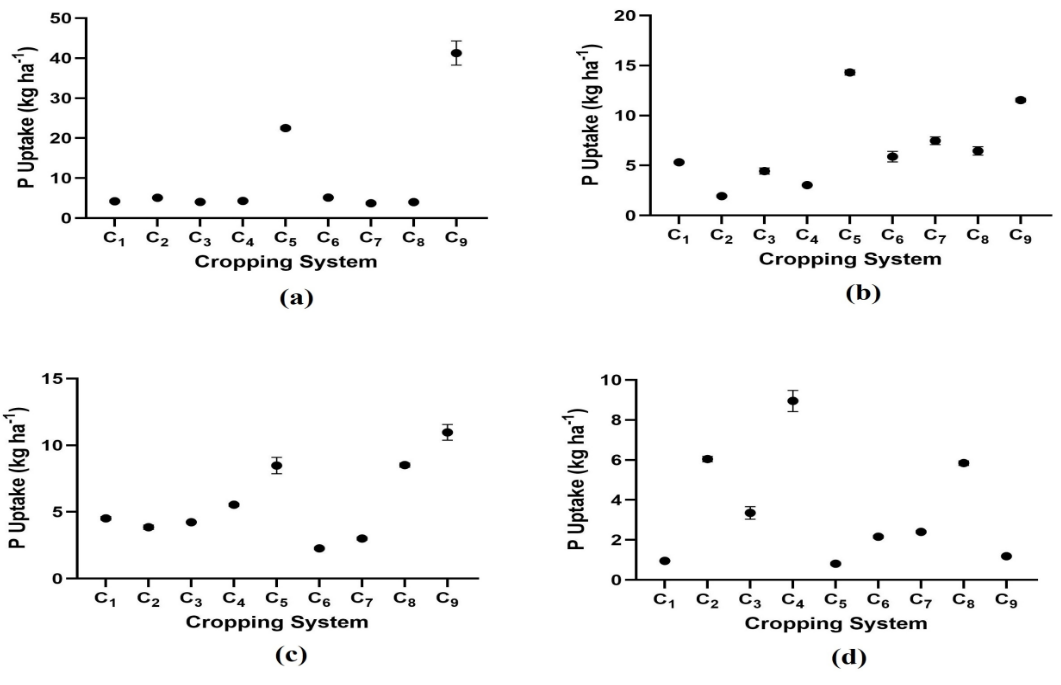

Fig. 6. (a) P uptake in seed during *Rabi* 2020-21, (b) P uptake in seed during *Kharif* 2021, (c) P uptake in straw during *Rabi* 2020-21 and (d) P uptake in straw during *Kharif* 2021

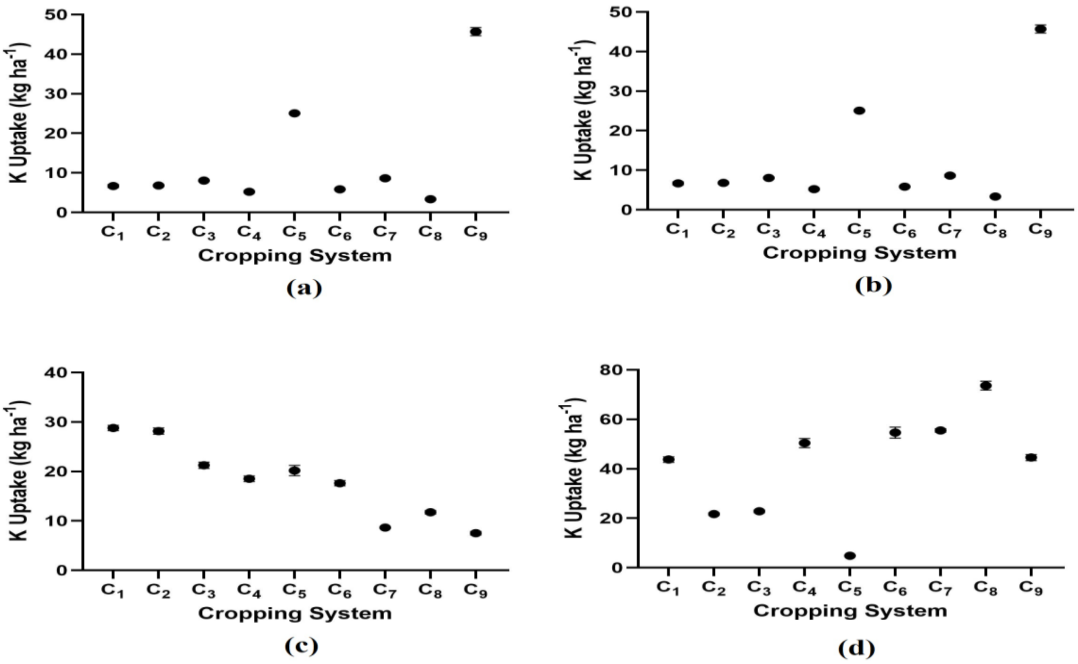

Fig. 7. (a) K uptake in seed during *Rabi* 2020-21, (b) (f) K uptake in seed during *Kharif* 2021, (c) K uptake in straw during *Rabi* 2020-21 and (d) K uptake in straw during *Kharif* 2021

3.4 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}.

Natural farming inputs *viz.* jeevamrit, ghanjeevamrit and mulching resulted in improved soil microbial activity leads to N mineralisation and N fixation by legumes attributed in increased N availability; resulted in higher N uptake by plants. Mogale et al. [19] 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 [20,21]. 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 [22].

3.5 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, 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}. Natural farming inputs *viz.* jeevamrit, ghanjeevamrit and mulching resulted in improved soil microbial activity attributed to enhanced P mineralization of native P and decomposition of ghanjeevamrit and mulching; resulted in improved P uptake. Tang et al. [23] and Sharma et al. [24] reported that significantly enhanced phosphorus use efficiency, resulting in higher seed and biomass phosphorus uptake, when cereals intercropped legumes.

3.6 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}.

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}. As nutrient uptake is dependent on the nutrient concentration and dry matter yield of the plant. Jeevamrit, ghanjeevamrit, mulching and legumes resulted in improved soil microbial activity attributed to enhanced dry matter by the increased availability and solubility of K in soil. While the low K uptake in crops due to low K content or less yield compared to other crops. The combination of legumes and cereals resulted in enhanced K uptake compared to sole cropping, overall increased yields and nutrient content [25]. Overall improved nutrient profile in intercropping legumes with cereals, including potassium uptake, particularly in systems like maize-legume intercropping [26].

3.7 Crude Protein

Crude protein content for the cropping system in *Rabi* 2020-21 and *Kharif* 2021, presented in the Table 3. 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

Table 3. 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

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 crude protein dependent on the dry matter accumulation, nutrient uptake as jeevamrit, ghanjeevamrit, mulching and legumes attributed to improved soil-physio-chemical and biological properties leads to higher nutrient uptake, resulted in enhanced crude protein content in the plant. The legumes significantly enhanced the crude protein content of the main crop due to their nitrogen-fixing ability [27,28]. The addition of legumes as intercrop (*viz*. black gram and cowpea) resulted in increased crude protein content in main crops [29, 30,31]. Legume as an intercrop improves main crops nutritional quality especially the crude protein content [32].

4. 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, C_4: cowpea - wheat + sarson, with C_7: maize + soybean – lentil and C_8: maize + cowpea - sarson). Enhanced NPK uptake in seeds and by-products was found significantly higher in legume-based cropping system compared to C_1 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. The legume-based systems not only improve soil fertility, but also resulted in increase in dry matter accumulation, enhanced nutrient uptake and crude protein content under natural farming.

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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