



# Deterministic Parameters of Growth and Yield of Wheat (*Triticum aestivum* L.) as Influenced by Fractional Application of Nitrogen and Potassium

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## 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

An experiment was conducted during the winter (*rabi*) seasons of 2020-21 and 2021-22 at Krishi Vigyan Kendra, Budgam- Shere Kashmir University of Agricultural Sciences and Technology, Kashmir, to evaluate the growth and yield variability of wheat as effected by split application of potassium (K) and nitrogen (N). The experiment was set up in a split-plot design replicated thrice with K splits as main plot factor and N splits as sub plot factor which resulted in 15 treatment combinations, viz. of K 30 kg/ha [K<sub>1</sub>: 100% as basal dose-(RFP); K<sub>2</sub>: 50% as basal dose + 50% at active tillering; K<sub>3</sub>: 25 % as basal dose + 75% at active tillering] and 5 treatments of N:120 kg/ha in split ratios of [N<sub>1</sub> : 50% as basal + 25% at jointing + 25% at booting stage (RFP); N<sub>2</sub>:25% as basal dose + 75% at active tillering; N<sub>3</sub> : 25% as basal dose +50% at active tillering + 25% at booting; N<sub>4</sub> : 50% as basal + 50% at active tillering; N<sub>5</sub> : 0% as basal + 75% at active tillering + 25% at booting]. The results revealed that growth parameters like dry matter accumulation, leaf area index, SPAD reading at various phenological stages and quality parameters like N content (%) of grain and straw, protein content of grain, yield and N use efficiency were significantly more with the application of K in two equal splits in the ratio of 50:50 as compared to the treatment where K was applied in one split as 100% basal dose. There was the non-significant effect of split application of K and N on days taken to different phenological stages. Increase in N content (%) of grain was 5.76 and 5.73% during the year 2020-21 and 2021-22, respectively. Average percent increase in grain yield, protein content of grain and N use efficiency (grain yield (kg)/kg N applied) with the application of K in two equal splits in the ratio of 50:50 during both the years was 12.46, 5.81 and 12.46% that was significantly higher as compared to recommended fertilizer application (K<sub>1</sub>).

**Keywords:** Grain yield; nitrogen content; nitrogen use efficiency; nitrogen and potassium splits; protein content; wheat yield.

## 1. INTRODUCTION

“Wheat crop by virtue of its potentiality is emerging as an important field crop under the Kashmir valley conditions. Globally, wheat grain is grown on more land area than any other commercial food. It is the leading source of vegetable protein in human food, having a higher protein content (12-18%) than other major cereals, maize or rice and contains about 70% starch and is the source of approximately half of the food calories consumed worldwide” [1]. “Since the area under wheat is almost stagnating and there is little scope for horizontal expansion. Therefore, development of wheat agronomy is pre-requisite. Many factors are responsible for increasing growth, yield and quality of wheat. Among these proper and balanced application of fertilizers is one of the most important factor contributing towards higher grain quality and productivity [2]. Potassium(K) and nitrogen(N) play a critical role for improving growth, yield and quality of wheat and K also improves water and nutrient use efficiency, improves stress tolerance, reduces incidence of pests and diseases, protect the plant against lodging, regulates the transport of water and nutrient, help in translocation and storage of

photosynthates, promotes protein and starch synthesis” [3]. “As the soils of Kashmir are dominated by illitic type of clay Minerals which affects the availability of K by fixing it in their interlayer sand wedge sides of soil clays and reduces the availability of K to growing plants [4] that affects the soil in general and particularly depletes the essential nutrients in the soil” [5]. “So to reduce the fixation of potassium and to increase its availability, split application of K according to the demand of a growing crop is the best agricultural technique. Timing of N application at pre-planting, stem elongation, heading and flowering or by increasing the number of split applications improves the growth, quality and grain yield of wheat” [6,7]. Thus, the present study entitled “Deterministic Parameters of Growth and Yield of Wheat (*Triticum aestivum* L.) as influenced by Fractional application of Nitrogen and Potassium” was carried out during *rabi* seasons of (2020-2021 and 2021-2022) at KVK Budgam, SKUAST-Kashmir, Shalimar with the following objective:

- To study the effect of split application of potassium and nitrogen on Growth and Quality of wheat.

## 2. MATERIALS AND METHODS

A field experiment was conducted during the winter (*rabi*) seasons of (2020–21 and 2021–22) at KVK Budgam, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K), Srinagar. The experiment was conducted on silty clay-loam soil, neutral in pH (7.08), medium in nitrogen (N) (380 kg/ha), available phosphorus (P) (18.2 kg/ha), and potassium (K) (160.1 kg/ha). The experiment comprised 2 factors viz. 3 treatments of K (K1, 100% K basal dose-recommended fertilizer practice; K2, 50% K as basal dose + 50% K at active tillering; K3, 25% K as basal dose + 75% K at active tillering) and 5 treatments of N [N1, 50% N as basal + 25% N at jointing + 25% N at booting stages (RFP); N2, 25% N as basal dose + 75% N at active tillering; N3, 25% N as basal dose + 50% N at active tillering + 25% N at booting; N4, 50% N as basal + 50% N at active tillering; N5, 0% N as basal + 75% N at active tillering + 25% N at booting] was laid out in a split-plot design with 3 replications. Sowing was done in the first week of October with row-to-row spacing of 30 cm. Recommended dose of N (120 kg/ha) and K (30 kg/ha) through urea and MOP respectively, was uniformly applied to each subplot as per the treatments while full dose of phosphorus (60 kg P<sub>2</sub>O<sub>5</sub>/ha) through Diammonium phosphate was applied as basal dose. In place of DAP, single superphosphate (375 kg/ha) was applied in those plots where 0% N was used as basal dose. Sowing was done manually at a distance of 23 cm apart from row to row using seed rate of 120kg/ha<sup>-1</sup> and seeds were placed 3-4 cm deep in furrows. Pre emergence herbicide Pendimethalin (30 EC) was applied plot wise @1kg a./ha<sup>-1</sup> three days after sowing and the first hand weeding was done after 35-40 DAS to flush out the autumn weeds and second hand weeding was done in the month of March to flush out the spring weeds. There was no requirement of irrigation due to sufficient availability of moisture during the crop growth. Due to observance of sporadic attack of yellow rust during the first year of experiment, Propaconazole (25 EC) was sprayed on 26<sup>th</sup> March @ 1ml/lit. with the help of Knapsack sprayer. Harvesting was done at physiological maturity after excluding two border rows breadth wise on each side of the plot and half of the meter length wise from other two sides. The harvested crop was allowed to dry in field for 48 hours and was piled into bundles. For the purpose of recording non-destructive parameters, five plants were randomly selected

and tagged in each sub plot of replications and then the average for Leaf Area Index (AccuparL-80), SPAD reading (SPAD-502 Konica Minolta Sensing) was worked out and recorded at various phenological stages. Penultimate rows from each side were used to collect samples for dry matter accumulation. Number of days taken by crop to reach various phenological stages viz. emergence, crown root initiation, active tillering, jointing, booting, heading, anthesis, milk, dough and maturity were recorded from each sub plot during both the years. The grain and straw samples were oven dried, grinded and sieved through 1mm size sieve, the straw and grain samples were analyzed for N content from each sub-plot separately. The protein content of the grain was worked out as;

$$\% \text{protein} = \% \text{N} \times 5.7 (\text{AACC}, 2000)$$

Nitrogen use efficiency (NUE) was calculated as;

$$\text{NUE} = \text{Grain yield (kg)/kg Nitrogen applied [8]}$$

Standard cultural practices were followed until the crop matured but the crop was cultivated as rainfed. The grain yield data was adjusted at 14% moisture content.

### 2.1 Statistical Analysis

The statistical analysis of the data was performed using Microsoft Excel and "Indostat" softwares. Statistical significance between mean differences among treatments for various parameters was analyzed using critical differences (CD) at 0.05 probability level.

## 3. RESULTS AND DISCUSSION

### 3.1 Growth Attributes and Grain Yield

The dry matter accumulation, LAI and SPAD values were significantly affected by split application of both potassium and nitrogen at all the stages of crop growth. Application of potassium in two equal splits in the ratio of 50: 50 (basal + active tillering) recorded significantly higher dry matter accumulation at maturity by 2.51 and 5.86% during the year 2020-21 and by 2.92 and 7.49% during the year 2021-22, respectively, over the treatment where potassium was given in two splits in the ratio of 25: 75 (basal + active tillering) and the treatment where potassium was given in one split as 100% basal dose (recommended practice) (Table 1). The LAI and SPAD reading continued to increase upto

anthesis and thereafter declined till harvest of the crop in all the treatments. It is because of the transition period from vegetative to reproductive phase as [9]. At anthesis the application of potassium in two splits in the ratios of 50: 50 (basal + active tillering) and in the ratio of 25: 75 (basal + active tillering) recorded significantly higher leaf area index (3.80; 3.78) and SPAD values (50.35 ; 47.91) during the year 2020-21 while 3.90; 3.84 and 51.15; 48.68 during the year 2021-22 as compared to the treatment where potassium was given in one split as 100% basal dose which recorded LAI (3.54 and 3.61) and SPAD values (45.28 and 45.98) respectively during both the years (Table 2; Fig. 1a). The increased dry matter accumulation, LAI, SPAD values with application of K in 2 equal splits leads to greater availability of K and lower transformation of potassium into non-exchangeable pool, where its availability regulates numerous biochemical, phenological, and physiological responses in plants [10,11] such as water uptake [12]; nutrient translocation [13], enzyme activation [14], photosynthesis [15], protein synthesis [16], osmoregulation [17] resulting in taller plants, more number of tillers and hence more dry matter accumulation [18], better foliage growth and hence higher leaf area index [19] and delay in leaf senescence that leads to higher SPAD values. Similar results were reported with the application of potassium in two equal splits as compared to 60 kg K<sub>2</sub>O/ha as basal [20]. The days taken to different phenological stages by wheat are illustrated graphically in Fig. 2a and 2b and shows that split application of potassium and nitrogen did not differ significantly. This is because days taken to different phenophases depends upon the two most important factors that affect rate of development in plants are photoperiod and temperature. These two factors were uniformly experienced by wheat crop in different plots and thus the development in all plants was uniform and the days taken to different phenological stages were the same. Similar findings were reported earlier [21]. Nitrogen content (grain and straw) and protein content in grain with the application of potassium in two equal splits in the ratios of 50: 50 (basal + active tillering) was at par with 25:75 (basal + active tillering) but significantly higher as compared to the treatment where potassium was given in one split as 100% basal dose (recommended practice) during both the years (Table 3). Greater availability of K in case of split application of K had the role in increasing translocation of photo assimilates from leaves to the grains [22] and

attributed to improved utilization of N and hence higher protein content [23]. These results are in confirmation with earlier results [24,25,26]. Potassium in two equal splits in the ratio of 50: 50 (basal + active tillering) recorded significantly maximum grain yield of 38.09 q ha<sup>-1</sup> and nitrogen use efficiency of 31.68 (kg grain yield/kg N applied) during the year 2020-21 and of 45.35 qha<sup>-1</sup> and 37.79 (kg grain yield/kg N applied) during the year 2021-22 as compared to the treatments where potassium was applied in two splits in the ratio of 25:75 (basal+ active tillering) and the treatment where potassium was applied in one split as 100% basal dose (recommended practice). The grain yield and nitrogen use efficiency with the application of potassium in the ratio of 25:75 (basal+ active tillering) was at par with the recommended practice (Table 3). Application of potassium in split doses enhanced the enzymatic activities, these reactions resulted in higher mobilization of nutrients in soil and plant and increased translocation of photosynthates in plant system, helps to produce large amounts of starch due to K-mediated carbohydrate metabolism leading to higher grain yield. Similar findings were reported earlier [3]. Maximum NUE in two equal splits of potassium might be due to prolonged availability of K in soil that promoted the absorption of top-dressed and soil applied N by plant that resulted in higher yield from same amount of nitrogen applied (120kg/ha) and hence higher NUE. Earlier reports suggest that split application of K in wheat promoted the absorption of top-dressed and soil applied N by plant [27,38].

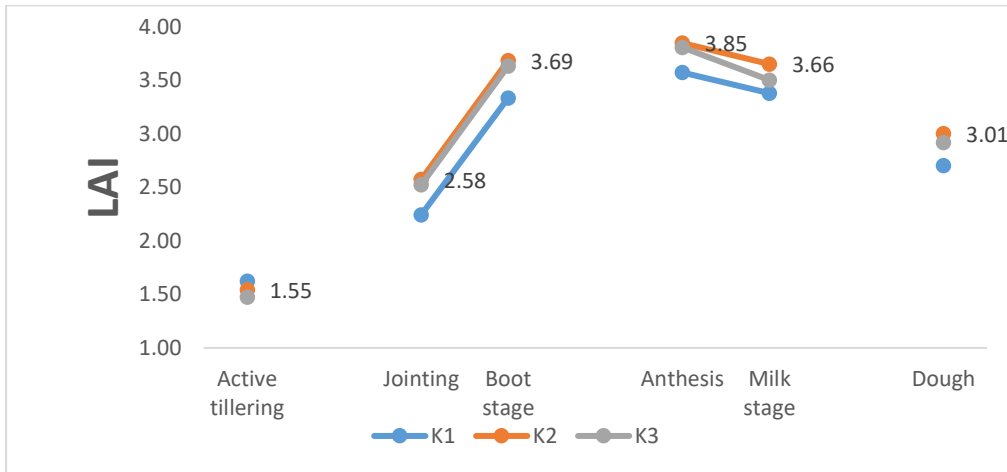
Further it is evident from the data, that the application of nitrogen in the ratio of 25: 50: 25 (basal + active tillering + booting) proved effective in enhancing various growth parameters at all phenological stages like dry matter production, leaf area index (3.90 at anthesis) and SPAD values (48.92 at anthesis) during the year 2020-21 while 3.98 and 49.90 during the year 2021-22 respectively (Fig. 1b and Table 2), as compared to the treatments where nitrogen was applied in the ratios of 50:25:25 (basal+jointing+booting), 25:75 (basal + active tillering), 50:50 (basal+active tillering) and 75: 25 (active tillering + booting). The increased dry matter production, leaf area index and SPAD values recorded with the application of nitrogen in three splits with reduced basal dose in the ratio of 25: 50: 25 might be attributed to the reduction in loss of nitrate by leaching during the wet growing season that results in adequate amount of nitrogen and its availability at critical

growth stages of wheat improves photosynthetic activity by improving chlorophyll content which leads to increasing cell division and elongation of cells that leads to higher dry matter production, increased leaf area and hence increased leaf area index [28] and also SPAD values. Similar results were reported with the application of nitrogen in splits who reported that nitrogen is considered as the prime nutrient and promote plant growth, and internode size result in increased plant height and hence dry matter accumulation [29]. These results are in confirmation with the earlier findings who also reported the increased leaf area index with the application of nitrogen in three splits as compared to two splits [6]. At harvest nitrogen content (straw and grain), Protein content % (grain) grain yield (380.9 and 453.5kg<sup>ha</sup><sup>-1</sup>) and highest NUE of 31.74 and 37.79 (kg grain/kg N applied) (Table 3) was recorded with three splits of nitrogen in the ratios of 25:50:25(basal+ active tillering + booting) was found at par with 50: 25: 25 (basal + jointing +booting) but significantly superior as compared to the treatments where nitrogen was applied in two splits in the ratios of 25:75 (basal + active tillering), 50: 50(basal +active tillering)and 75:

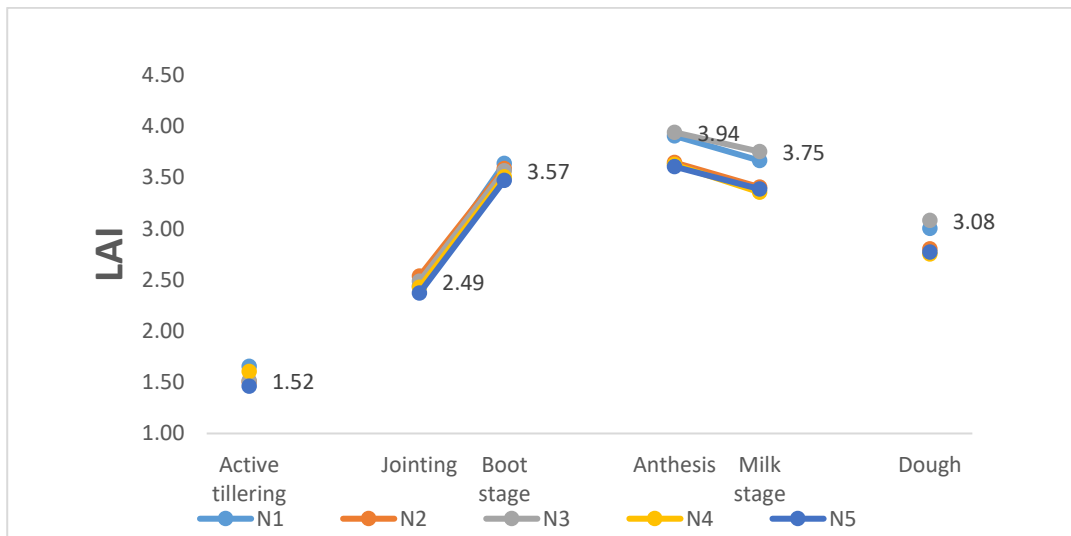
25(active tillering+booting). The possible reason of higher grain and straw nitrogen content at harvest might be due to the adequate availability of nitrogen throughout the crop growth period in the plots received nitrogen in three splits that resulted in translocation of more nitrogen to grains and straw. Similar results were obtained by increased nitrogen content in grain and straw by the wheat crop when N was applied in three splits [30,31], further, splitting of N fertilizer to many doses increasedthe efficiency of the fertilizers by decreasing leaching losses of NO<sup>-3</sup> to a large extent and increased both yield and quality of crops [32,33,34,35]. These results are in confirmation with the earlier findings [36] who reported that N in three splits with reduced basal dose results in efficient utilization by arresting the volatilization or leaching down of nitrogen due to which plants don't suffer any shortage in nitrogen throughout life cycle which led to an increase in yield component and consequently grain yield. These results regarding enhanced grain yield due to split application of nitrogen are ascertained also by earlier experiments [37,38,39].

**Table 1. Dry matter accumulation (kg<sup>ha</sup><sup>-1</sup>) at various growth stages of wheat crop as influenced by split application of potassium and nitrogen (Pooled data of 2 years)**

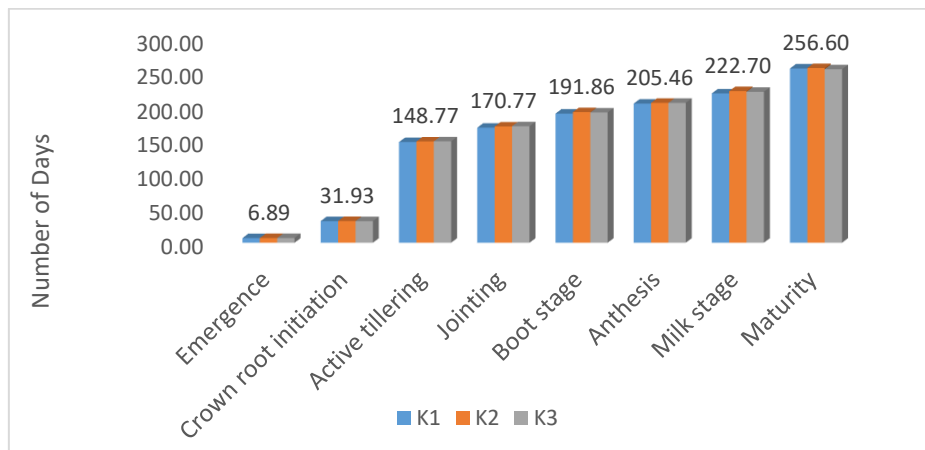
Treatments	Active tillering	Jointing	Boot stage	Anthesis	Milk stage	Dough	Maturity
K1	549.5	1491	3651.5	5739	9432	10711	11152
K2	499.5	1639	4111.5	5981.5	9848	11437	11904
K3	445	1530	3939	5873	9735	11143	11587
<b>SEm±</b>	<b>20</b>	<b>23</b>	<b>69.5</b>	<b>35.5</b>	<b>55</b>	<b>108</b>	<b>68</b>
<b>CD (p=0.05)</b>	<b>61</b>	<b>70</b>	<b>215.5</b>	<b>107.5</b>	<b>176</b>	<b>327</b>	<b>208.5</b>
N1	541.5	1562	3976.5	5934	9778	11217	11597.5
N2	503	1612	3962.5	5890	9733	11115	11537
N3	489.5	1592.5	3989.5	5948	9814	11350	11789
N4	514.5	1545.5	3773.5	5761	9511	10863	11438
N5	441.5	1505.5	3802.5	5788.5	9523	10937	11376
<b>SEm±</b>	<b>15.5</b>	<b>16.5</b>	<b>39.5</b>	<b>31</b>	<b>49</b>	<b>100</b>	<b>42.5</b>
<b>CD (p=0.05)</b>	<b>46</b>	<b>49</b>	<b>115.5</b>	<b>90.5</b>	<b>144</b>	<b>293</b>	<b>125.5</b>
<i>100% as basal dose</i>		<i>K1</i>	<i>50% as basal+25% at jointing +25% at booting stages</i>				<i>N1</i>
<i>50% as basal dose + 50% at active tillering</i>		<i>K2</i>	<i>25% as basal+75% at active tillering</i>				<i>N2</i>
<i>25% as basal dose + 75% at active tillering</i>		<i>K3</i>	<i>25% as basal+50% at active tillering + 25% at booting</i>				<i>N3</i>
			<i>50% as basal+50% at active tillering</i>				<i>N4</i>
			<i>0% as basal+75%at active tillering+25% at booting</i>				<i>N5</i>



**Fig. 1a. Leaf area index at various growth stages of wheat Crop as Influenced by split application of Potassium**



**Fig. 1b. Leaf area index at various growth stages of wheat Crop as Influenced by split application of nitrogen**



**Fig. 2a. Days taken to different phenological stages as influenced by split application of potassium in wheat**

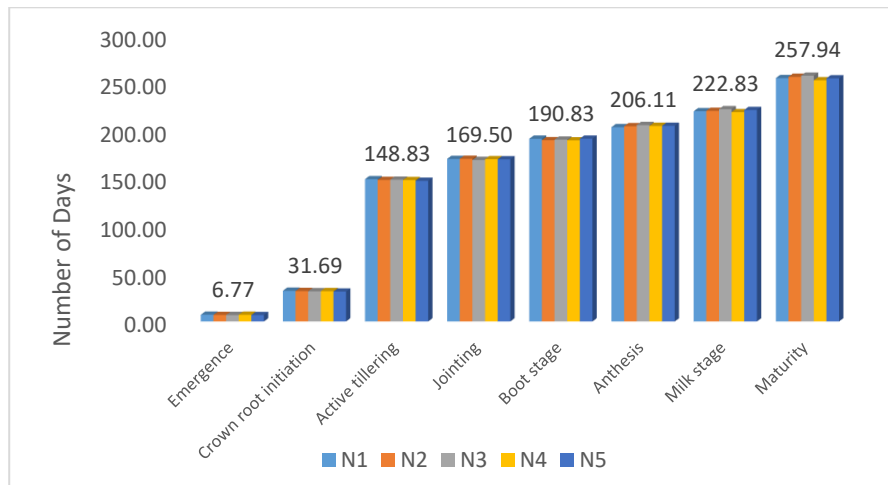


Fig. 2b. Days taken to different phenological stages as influenced by split application of nitrogen in wheat

Table 2. SPAD reading of wheat crop as influenced by split application of potassium and nitrogen (Pooled data of 2 years)

Treatments	Active tillering	Jointing	Boot stage	Anthesis	Milk stage	Dough	Maturity
K1	40.4	44.0	44.8	45.6	40.0	35.7	26.2
K2	36.8	49.3	50.2	50.8	44.6	39.4	32.1
K3	33.6	45.8	47.7	48.3	41.7	37.8	28.6
<b>SEm±</b>	<b>1.4</b>	<b>1.1</b>	<b>0.7</b>	<b>1.0</b>	<b>0.7</b>	<b>0.7</b>	<b>0.8</b>
<b>CD (p=0.05)</b>	<b>4.1</b>	<b>3.3</b>	<b>2.0</b>	<b>2.9</b>	<b>2.2</b>	<b>2.0</b>	<b>2.5</b>
N1	38.5	44.9	48.0	49.4	43.7	38.8	29.7
N2	36.5	48.6	49.0	49.3	41.1	36.5	28.6
N3	36.7	47.9	48.5	49.4	43.9	39.9	30.6
N4	39.2	45.7	46.1	47.1	40.8	36.4	27.6
N5	33.8	44.8	45.5	46.5	41.2	36.7	28.3
<b>SEm±</b>	<b>0.9</b>	<b>0.9</b>	<b>0.7</b>	<b>0.7</b>	<b>0.7</b>	<b>0.7</b>	<b>0.8</b>
<b>CD (p=0.05)</b>	<b>2.7</b>	<b>2.7</b>	<b>2.1</b>	<b>2.1</b>	<b>1.9</b>	<b>2.2</b>	<b>2.4</b>
100% as basal dose			K1	50% as basal+25% at jointing+25% at booting stages			N1
50% as basal dose+50% at active tillering			K2	25% as basal+75% at active tillering			N2
25% as basal dose+ 75% at active tillering			K3	25% as basal+50% at active tillering+25% at booting			N3
				50% as basal+50% at active tillering			N4
				0% as basal+75%at active tillering +25% at booting			N5

Table 3. Nitrogen content (%), total, protein content and nutrient use efficiency (kg grain yield/kgN applied as influenced by split application of potassium and nitrogen (pooled data of 2 years)

	Nitrogen content (%)		Total	Protein content in grain (%)	Grain Yield (q/ha)	Nitrogen use efficiency(kg grain yield/kg N applied)
	Grain	Straw				
K1	1.56	0.38	1.94	1.96	37.075	30.895
K2	1.65	0.41	2.06	2.08	41.72	34.765
K3	1.63	0.40	2.03	2.05	38.645	32.205

	Nitrogen content (%) Grain Straw		Total	Protein content in grain (%)	Grain Yield (q/ha)	Nitrogen use efficiency(kg grain yield/kg N applied)
<b>SEm±</b>	<b>0.02</b>	<b>0.004</b>	0.024	0.024	0.55	0.445
<b>CD(p=0.05)</b>	<b>0.06</b>	<b>0.013</b>	0.073	0.074	1.67	1.385
N1	1.66	0.41	2.07	2.09	40.35	33.625
N2	1.58	0.39	1.97	1.99	37.345	31.12
N3	1.71	0.42	2.13	2.13	42.755	35.63
N4	1.51	0.37	1.88	1.91	36.76	30.635
N5	1.60	0.40	2	2.02	38.41	32.005
<b>SEm±</b>	<b>0.02</b>	<b>0.005</b>	0.025	0.02	0.69	0.575
<b>CD(p=0.05)</b>	<b>0.06</b>	<b>0.016</b>	0.	0.06	2.03	1.69
100% as basal dose		K1	50% as basal+25%at jointing+25% at booting stages			N1
50% as basal dose+50% at active tillering		K2	25%as basal+75%at active tillering			N2
25% as basal dose + 75% at active tillering		K3	25%as basal+50% at active tillering+25% at booting			N3
			50% as basal+50% at active tillering			N4
			0% as basal+75% at active tillering+25% at booting			N5

#### 4. CONCLUSION

Due to illitic type of clay minerals and adverse environmental conditions in temperate Kashmir during winter months, which affects the availability of potassium (K) by fixing it in the interlayer and wedge sides of soil clay, and higher basal nitrogen (N) dose gets subjected to leaching losses before plant uptake. The current recommendation of 100% K as basal dose and 50% N as basal dose is not adequate to synchronize K and N supply with actual crop K and N demand. The increase in growth, yield, nitrogen content (grain and straw), protein content (grain) and N use efficiency with the split application of K and N with reduced basal dose had proved that the wheat crop requires K in two equal splits 50: 50 (basal + active tillering) and lower dose of N at the early stages (25%N as basal dose) and more N during its grand growth period (50% N at active tillering + 25% N at booting). Thus, split application of potassium 30 kg Kha<sup>-1</sup> in two equal splits and N 120 kg ha<sup>-1</sup> in three splits with reduced basal dose (25: 50: 25) could help in synchronization of K and N requirements to its peak demand by the crop for increased nutrient, protein content and yield in wheat.

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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