

Growth and Quality Parameters of Wheat (*Triticum aestivum* L.) as Influenced by Split Application of Nitrogen and Potassium

ABSTRACT

An experiment was conducted during the winter (*rabi*) seasons of 2020-21 and 2021-22 at Krishi Vigyan Kendra, Budgam- Sher-e-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 Potassium-K splits as main plot factor and nitrogen-N splits as sub plot factor which resulted in 15 treatment combinations, viz. of potassium-K @ 30 kg/ha [K₁: 100% as basal dose-(RFP); K₂: 50% as basal dose + 50% at active tillering; K₃: 25 % as basal dose + 75% at active tillering] and 5 treatments of nitrogen-N @ 120 kg/ha in split ratios of [N₁ : 50% as basal + 25% at jointing + 25% at booting stage (RFP); N₂: 25% as basal dose + 75% at active tillering; N₃ : 25% as basal dose + 50% at active tillering + 25% at booting; N₄ : 50% as basal + 50% at active tillering; N₅ : 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 nitrogen content (%) of grain and straw, protein content of grain, yield and nitrogen use efficiency were significantly more with the application of Potassium-K in two equal splits in the ratio of 50:50 as compared to the treatment where potassium-K was applied in one split as 100% basal dose. There was the non-significant effect of split application of potassium-K and Nitrogen on days taken to different phenological stages. Increase in Nitrogen 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 nitrogen use efficiency (grain yield (kg)/kg N applied) with the application of potassium-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 (K₁).

Keywords: Grain yield, Nitrogen content, Nitrogen Use efficiency, Nitrogen and Potassium splits, Protein content, Wheat yield.

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 (Khalid *et al.*, 2023). 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

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- 3) The manuscript should be revised as per suggestions.

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proper and balanced application of fertilizers is one of the most important factors contributing towards higher grain quality and productivity (Wanjari *et al.*, 2022). Potassium (K) and nitrogen (N) play a critical role for improving growth, yield and quality of wheat and potassium (K) also improves water and nutrient use efficiency, improves stress tolerance, reduces incidence of pests and diseases, protects the plant against lodging, regulates the transport of water and nutrient, helps in translocation and storage of photosynthates, promotes protein and starch synthesis (Seema and Singh, 2020).

As the soils of Kashmir are dominated by illitic type of clay minerals which affect the availability of K by fixing it in the interlayers and wedgesides of silicates of soil clays and reduces the availability of K to growing plants (Seema and Singh, 2021) that affects the soil productivity soil productivity in general and particularly depletes the essential nutrients in the soil (Akhter *et al.*, 2017). 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 (Saeed *et al.*, 2013 and Akram *et al.*, 2014). Thus, the present study entitled “quality and growth parameters of wheat as influenced by split application of nitrogen and potassium under temperate conditions of Kashmir” 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.

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 potassium (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 nitrogen (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 nitrogen (N) (120 kg/ha) and potassium (K) (30 kg/ha) through urea and muriate of potash respectively, was uniformly applied to each subplot as per the treatments while full dose of phosphorus (60 kg P₂O₅/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 120 kg/ha⁻¹ and seeds were placed 3-4 cm deep in furrows. Pre emergence herbicide Pendimethalin (30 EC) was applied plot wise @ 1 kg a.i./ha⁻¹ 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, Propanazole (25 EC) was sprayed on 26th March @ 1 ml/l⁻¹ 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 the other two sides. The harvested crop was allowed to dry in field for 48 hours and was piled into bundles. For the

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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;

$$\text{NUE} = \frac{\text{Grain yield (kg)}}{\text{kg Nitrogen applied}} (\text{Sowers et al., 1994})$$

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. 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.

RESULTS AND DISCUSSION

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 percent during the year 2020-21 and by 2.92 and 7.49 percent 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 up to 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 also reported by Alam, 2013. 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 (Hasanuzzaman et al., 2018; Johnson et al., 2022) such as water uptake (Sardans and Peñuelas 2015); nutrient translocation (Xu et al. 2020), enzyme activation (Hasanuzzaman et al. 2020), photosynthesis (Siddiqui et al., 2021), protein synthesis (Sahiet et al., 2021), osmoregulation (Wang et al. 2013) resulting in taller plants, more number of tillers and hence more dry matter accumulation (Wagnan et al., (2002), better foliage growth and hence higher leaf area index (Marschner, 1995) and delay in leaf senescence that leads to higher SPAD values. Mathukia et

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al. (2014) also reported similar results with the application of potassium in two equal splits as compared to 60 kg K₂O/ha as basal. 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 were the findings of Nawab *et al.* (2011). 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 (EL-Abady *et al.*, 2009) and attributed to improved utilization of N and hence higher protein content (Bhatia and Singh, 2015). These results are in confirmation with Fusheng (2006), Zou *et al.* (2006), El-Ashry and El-Kholy (2005). Potassium in two equal splits in the ratio of 50:50 (basal + active tillering) recorded significantly maximum grain yield of 38.09 q ha⁻¹ and nitrogen use efficiency of 31.68 (kg grain yield/kg N applied) during the year 2020-21 and of 45.35 q ha⁻¹ 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 by Sharma and Singh (2020). 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 (120 kg/ha) and hence higher NUE. Yu *et al.* (2007) also reported that split application of K in wheat promoted the absorption of top-dressed and soil applied N by plant.

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 (Haile *et al.*, 2012) and also SPAD values. Khan *et al.* (2022) also reported the similar results 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. These results are in confirmation with the findings of Saeed *et al.* (2013) who also reported the increased leaf area index with the application of nitrogen in three splits as compared to two splits. At harvest nitrogen content (straw and grain), Protein content % (grain) grain yield (38.09 and 45.35 g ha⁻¹) 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. Masaka, (2006) and Khan *et al.* (2009) also registered increased nitrogen content in grain and straw by the wheat crop when nitrogen was applied in three splits, further, splitting of nitrogen fertilizer to many doses increased the efficiency of the fertilizers by decreasing leaching losses of NO₃ to a large extent and increased both yield and quality of crops (Gaueret *et al.*, 1992; Patkeet *et al.*, 2003; Shalaby *et al.*, 2006 and Ali, 2010). These results are in confirmation with the findings of Ali (2011) 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 Abedi *et al.* (2011).

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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 nitrogen use efficiency with the split application of potassium and nitrogen with reduced basal dose had proved that the wheat crop requires potassium in two equal splits 50: 50 (basal + active tillering) and lower dose of nitrogen 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⁻¹ in two equal splits and nitrogen 120 kg ha⁻¹ in three splits with reduced basal dose (25: 50: 25) could help in synchronization of potassium and nitrogen requirements to its peak demand by the crop for increased nutrient, protein content and yield in wheat.

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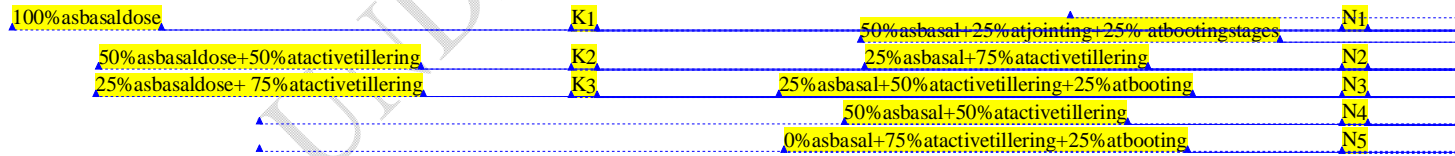
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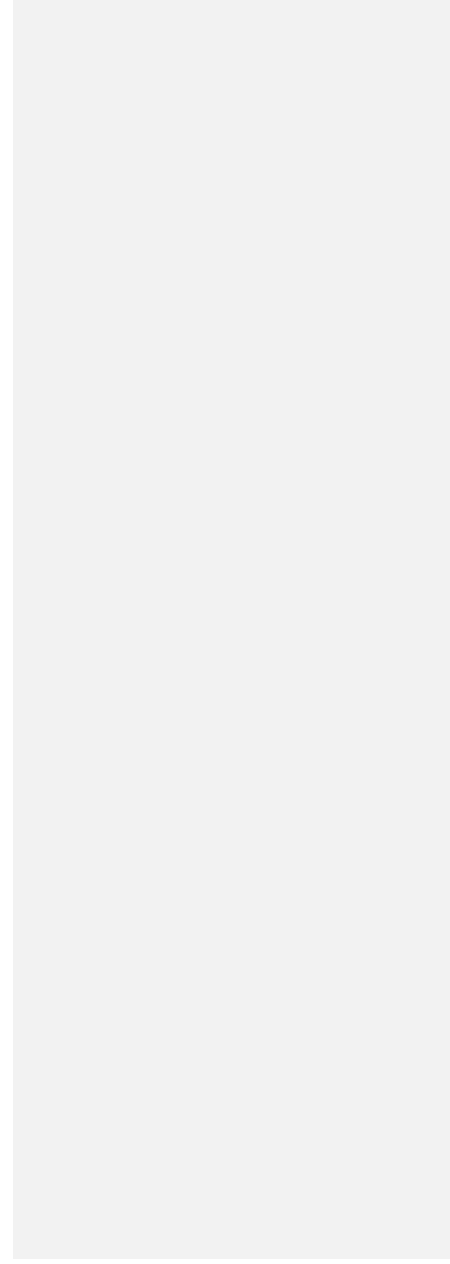
Table1: Drymatter accumulation (qha^{-1}) at various growth stages of wheat crop as influenced by split application of potassium and nitrogen

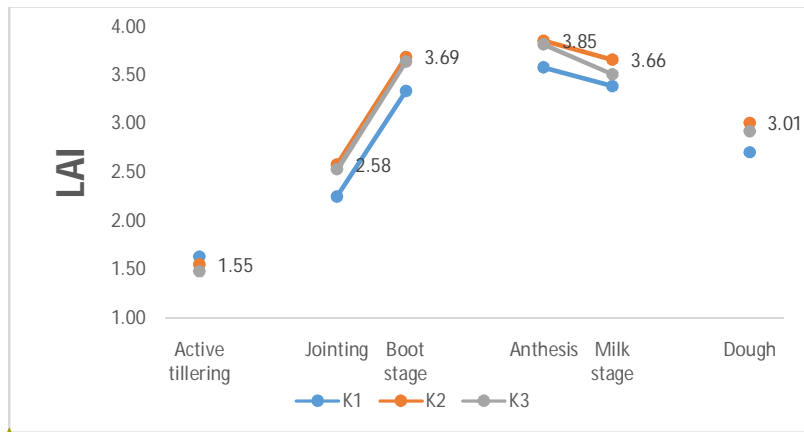
Treatments	Activetillering		Jointing		Bootstage		Anthesis		Milkstage		Dough		Maturity	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
K1	5.04	5.95	13.12	16.70	34.55	38.48	50.39	64.39	85.72	102.92	99.68	114.53	102.72	120.32
K2	4.78	5.21	14.15	18.63	38.75	43.48	51.85	67.78	88.88	108.08	105.72	123.01	108.74	129.34
K3	4.25	4.65	13.61	16.99	35.73	43.05	51.23	66.23	88.25	106.45	103.58	119.27	106.07	125.67
SEm±	0.31	0.09	0.23	0.23	0.25	1.14	0.27	0.44	0.55	0.55	0.76	1.40	0.66	0.70
CD(p=0.05)	0.91	0.31	0.70	0.70	0.75	3.56	0.82	1.33	1.76	1.76	2.21	4.33	2.01	2.16
N1	5.18	5.65	13.69	17.55	36.75	42.78	51.84	66.84	88.78	106.78	103.76	120.57	106.57	125.38
N2	4.73	5.33	14.19	18.05	36.60	42.65	51.40	66.40	87.83	106.83	103.10	119.20	105.61	125.13
N3	4.45	5.34	14.05	17.80	37.21	42.58	51.98	66.98	89.14	107.14	105.44	121.56	108.30	127.48
N4	4.91	5.38	14.03	16.88	35.28	40.19	50.11	65.11	86.11	104.11	100.63	116.62	104.23	124.53
N5	4.18	4.65	13.18	16.93	35.90	40.15	50.44	65.33	86.23	104.23	102.02	116.72	104.51	123.01
SEm±	0.15	0.16	0.16	0.17	0.21	0.58	0.27	0.35	0.49	0.49	0.81	1.18	0.42	0.43
CD(p=0.05)	0.46	0.46	0.49	0.49	0.61	1.70	0.80	1.01	1.44	1.44	2.38	3.47	1.24	1.27



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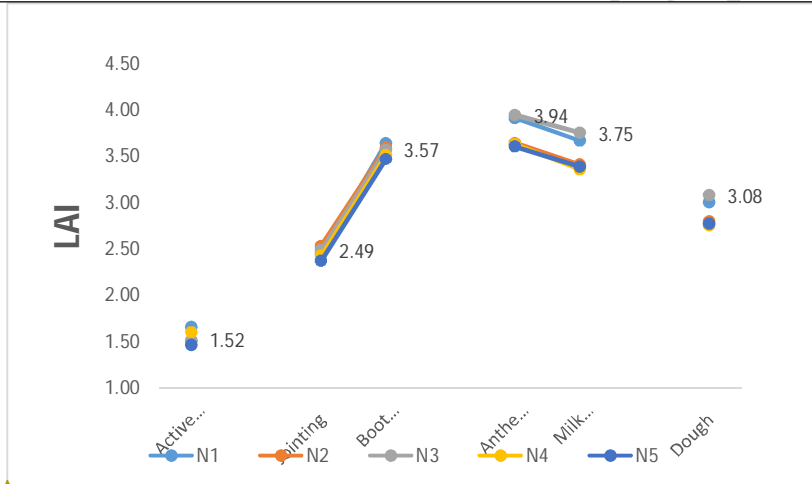




Comment [U12]: Tables is more suitable than Figures 1a, 1b.

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Fig. 1a: Leafareaindexatvariousgrowthstagesofwheat Crop asInfluencedbysplitapplicationofpotassium



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Fig. 1b: LeafareaindexatvariousgrowthstagesofwheatCropasInfluencedbysplitapplicationofnitrogen

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Table 2: SPAD reading of wheat crops influenced by split application of potassium and nitrogen

Treatments	Active tillering		Jointing		Bootstage		Anthesis		Milkstage		Dough		Maturity	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
K1	39.79	40.94	43.24	44.70	44.12	45.43	45.28	45.98	39.68	40.40	34.88	36.61	25.54	26.91
K2	35.87	37.82	48.30	50.30	49.87	50.45	50.35	51.15	43.87	45.39	38.43	40.46	31.50	32.65
K3	32.60	34.52	45.36	46.29	46.96	48.38	47.91	48.68	41.04	42.26	36.94	38.64	27.91	29.28
SEm±	1.34	1.36	1.18	0.98	0.71	0.62	0.82	1.13	0.95	0.51	0.67	0.64	0.82	0.81
CD(p=0.05)	4.06	4.17	3.57	3.00	2.13	1.88	2.46	3.39	2.86	1.54	2.04	2.01	2.46	2.44
N1	37.71	39.36	44.14	45.75	46.93	49.13	48.88	49.83	43.36	43.98	37.85	39.74	29.00	30.37
N2	35.61	37.38	48.11	49.00	48.84	49.10	48.87	49.70	40.27	41.89	35.76	37.32	27.91	29.28
N3	35.82	37.48	47.06	48.67	47.90	49.00	48.92	49.90	43.55	44.17	38.81	40.98	29.96	31.33
N4	38.34	39.99	44.86	46.46	45.55	46.64	47.07	47.08	40.12	41.41	35.62	37.18	27.15	28.14
N5	32.95	34.60	44.00	45.60	44.38	46.58	45.50	47.51	40.35	41.97	35.72	37.63	27.57	28.95
SEm±	0.98	0.87	0.91	0.96	0.78	0.65	0.82	0.65	0.71	0.61	0.64	0.85	0.82	0.80
CD(p=0.05)	2.88	2.54	2.65	2.80	2.27	1.92	2.39	1.89	2.07	1.80	1.89	2.48	2.39	2.34

Comment [U13]: Please show average values of years 2013 and 2014 as well.

Comment [U14]: Years 2021 and 2022?

100% as basal dose

50% as basal dose + 50% at active tillering

25% as basal dose + 75% at active tillering

K1

K2

K3

50% as basal + 25% at jointing + 25% at booting stages

25% as basal + 75% at active tillering

25% as basal + 50% at active tillering + 25% at booting

50% as basal + 50% at active tillering

0% as basal + 75% at active tillering + 25% at booting

N1

N2

N3

N4

N5

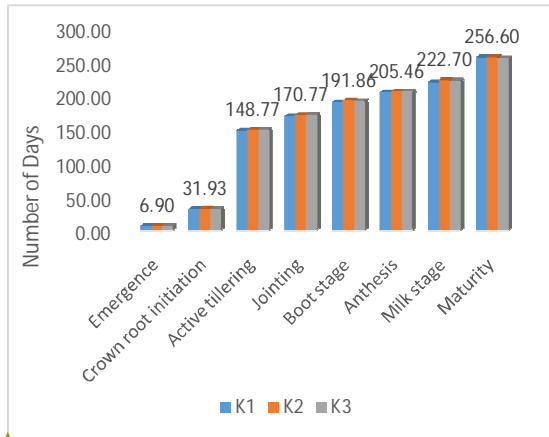


Fig. 2a: Daystaken todifferent phenologicalstages as influenced bysplitaApplicationofpotassiumin wheat

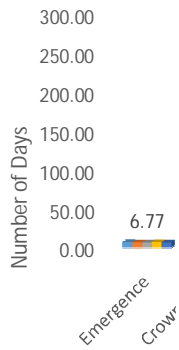


Fig. 2b: Daystaken todifferent phenologicalstages as influenced bysplitaApplicationofNitrogen in wheat

Comment [U15]: Figures should be prepared by using a sigmaplot software to get high resolution.

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Table3: Nitrogencontent(%),proteincontentandnutrientuseefficiency(kggrainyield/kgNAppliedasinfluencedby split applicationofpotassiumand nitrogen

Comment [U16]: Please show average values of years 2020 and 2021 as well.

Treatments	Nitrogencontent (%)				Protein contentin grain (%)		GrainYield (q/ha)		Nitrogen useefficiency(kg grain yield/kgNApplied)	
	2020 Grain	Straw	2021 Grain	Straw	2020	2021	2020	2021	2020	2021
K1	1.56	0.38	1.57	0.39	8.91	8.97	34.01	40.14	28.34	33.45
K2	1.65	0.41	1.66	0.42	9.43	9.49	38.09	45.35	31.74	37.79
K3	1.63	0.40	1.64	0.41	9.31	9.37	35.57	41.72	29.64	34.77
SEm±	0.02	0.004	0.02	0.004	0.11	0.12	0.70	0.40	0.57	0.32
CD(p=0.05)	0.06	0.013	0.06	0.014	0.34	0.37	2.13	1.21	1.77	1.00
N1	1.66	0.41	1.67	0.42	9.58	9.56	37.18	43.52	30.98	36.27
N2	1.58	0.39	1.59	0.40	8.96	9.03	34.09	40.60	28.40	33.84
N3	1.71	0.42	1.70	0.43	9.78	9.92	39.50	46.01	32.91	38.35
N4	1.51	0.37	1.52	0.39	8.60	8.66	33.42	40.10	27.85	33.42
N5	1.60	0.40	1.61	0.41	9.17	9.22	35.04	41.78	29.20	34.81
SEm±	0.02	0.005	0.016	0.004	0.12	0.11	0.70	0.68	0.58	0.57
CD(p=0.05)	0.06	0.016	0.048	0.012	0.36	0.37	2.06	2.00	1.71	1.67

100% asbasaldose	K1	50% asbasal+25% atjointing+25% atbootingstages	N1
50% asbasaldose+50% atactivetillering	K2	25% asbasal+75% atactivetillering	N2
25% asbasaldose+ 75% atactivetillering	K3	25% asbasal+50% atactivetillering+25% atbooting	N3
		50% asbasal+50% atactivetillering	N4
		0% asbasal+75% atactivetillering+25% atbooting	N5

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