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Growth and yield variability of wheat as effected by split application of potassium and nitrogen

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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- 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 and nitrogen. The experiment was set up in a split-plot design replicated thrice with Potassium splits as main plot factor and nitrogen splits as sub plot factor which resulted in 15 treatment combinations, *viz*. of potassium @ 30 kg/ha [K_1: 100% as basal dose-(RFP); K_2: 50% as basal dose + 50% at active tillering; K_3: as basal dose + 75% at active tillering] and 5 treatments of nitrogen @ 120 kg/ha in split ratios of [N_1 : 50% as basal + 25% at jointing + 25% at booting stage (RFP); N_2: 25% as basal dose + 75% at active tillering; N_3 : 25% as basal dose +50% at active tillering + 25% at booting; N_4 : 50% as basal + 50% at active tillering; N_5 : 0% as basal + 75% at active tillering + 25% at booting]. The results revealed that growth parameters like plant height, number of tillers (m-2) and dry matter accumulation at various phenological stages were higher with the application of potassium in two equal splits in the ratio of 50:50 as compared to the treatment where potassium was applied in one split as 100% basal dose. The mean increase in plant height during the year 2020-21 and 2021-22 was 7.24% at jointing, 9.01% at boot stage, 8.93% at Anthesis, 8.6% at milk stage, 8.35% at Dough stage and 8.31% at maturity in case of 50:50 as compared to 100% as basal dose. Application of nitrogen in three splits with reduced basal dose in the ratio of 25:50:25 resulted in improved plant height, number of tillers (m-2), dry matter accumulation at various phenological stages as compared to recommended practice. Application of potassium in two equal splits in the ratio of 50: 50 (basal + active tillering) with the application of nitrogen in three splits in the ratio of 25: 50: 25 (basal + active tillering + booting) recorded higher grain yields as compared to other treatment combinations.

Keywords: Plant height, dry matter, nitrogen and potassium splits, 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) [11]. 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 (Wanjari *et al*., 2022) [23]. Potassium and nitrogen plays a critical role for improving growth, yield and quality of wheat and potassium 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 (Seema and Singh., 2020) [16].
As the soils of Kashmir are dominated by illicit type of clay minerals which affects the availability of K by fixing it in the interlayers and wedge sides of soil clays and reduces the

availability of K to growing plants (Seema and Singh., 2021) [17] that affects the soil productivity in general and particularly depletes the essential nutrients in the soil (Akhter *et al*., 2017) [3-4]. 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 preplanting, stem elongation, heading and flowering or by increasing the number of split applications improves the grain yield of wheat and tiller formation and survival of tillers, plant height, dry matter accumulation, LAI and chlorophyll content (Saeed *et al*., 2013 and Akram *et al*., 2014) [14, 6]. Thus, the present study entitled "Growth and Yield Variability of Wheat as Effected by Split Application of Potassium and Nitrogen Under temperate 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 yield 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 (380 kg/ha), available phosphorus (18.2 kg/ha), and potassium (160.1 kg/ha). The experiment comprised 2 factors *viz*. 3 treatments of potassium (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 [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 (120 kg/ha) and potassium (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 P2 O5 /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. Standard cultural practices were followed until the crop matured but the crop was cultivated as rainfed crop. Plant height and number of tillers/m^2 and dry weight at various phenological stages were recorded from 5 random plants in each subplot. 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

Significantly taller plants at various phenological stages (jointing to maturity; Table 1) and higher number of tillers/m^2 (Fig. 1) were recorded with the application of potassium in 2 equal splits in the ratio of 50:50 (basal + active tillering) as compared to the treatments where potassium was applied in 2 splits in the ratio of 25:75 (basal + active tillering) and the treatment where potassium was given in once split as 100% basal dose (recommended practice). There was the continuous increase in plant height from jointing to dough stage. While the number of tillers/m^2 decreases from jointing to As the 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) [9] such as water uptake (Sardans and Peñuelas 2015) [15]; nutrient translocation (Xu *et al*. 2020) [24], enzyme activation (Hasanuzzaman *et al*. 2020) [10], photosynthesis (Siddiqui *et al*. 2021) [18], protein synthesis (Sahi *et al*. 2021), osmoregulation (Wu and WeiHua 2013), energy transfer (Sardans and Peñuelas 2021) [15], stomatal opening mechanism (Anokye *et al*. 2021), and stress resistance, i.e., salinity (Adhikari *et al*. 2020), drought (Abd El-Mageed *et al*. 2017), heat (Singh and Singh 2020) [19], and heavy metals (Yasin *et al*. 2018). An optimum supply of K during the entire crop growth period was found to be more effective in improving growth parameters, yield attributes and yield. Improved growth parameters of wheat with the application of potassium in 2 equal splits was also reported by Wani *et al*. (2014) [22], Ahmed *et al*., (2017) [2]. With respect to nitrogen splits, significantly higher plant height and increase in number of tillers/m^2 (Fig. 1) were recorded with the application of nitrogen in 3 splits with reduced basal dose in the ratio of 25 : 50 : 25 (basal + active tillering + booting) 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). This is due to the fact that nitrogen promotes growth and development and enhances synthesis and accumulation of proteins, amino acids and enzymes which are responsible for cell division and cell elongation. The statement is in close conformity with Saeed *et al*. (2012) [14]. Similar were the findings observed by Wagnan *et al*. (2002) [21], Akram *et al*. (2012) [5] and Amani *et al*. (2020) [7].

Application of potassium in two equal splits in the ratio of 50: 50 (basal + active tillering) along with the application of nitrogen in the ratio of 25: 50: 25 (basal + active tillering + booting) recorded significantly higher dry matter accumulation at maturity (110.24 q ha^{-1}) (Table 2). This might be attributed to the enhancement effect of splitting of potassium and nitrogen on growth, due to the favorable influence of these nutrients on metabolism and biological activity and the stimulating effect of potassium on photosynthetic pigments and enzyme activity which in turn encourage vegetative growth of plants and hence more dry matter accumulation (Ahmad *et al*., 2011) [1]. These findings are also in close confirmation with the findings of Lu *et al*. (2014) [12]. The interaction effect between potassium and nitrogen splits on grain yield was also found significant during both the years (Table 3). Data revealed that higher grain yield (43.39 q ha^{-1}) was recorded with the application of potassium in two equal splits in the ratio of 50: 50 (basal + active tillering) with the application of nitrogen in three splits in the ratio of 25: 50: 25 (basal + active tillering + booting) and was at par with 50: 25: 25 (basal + jointing + booting) but significantly higher than other treatment combinations. Wheat yield response to fertilizer-K depends on the N nutrition level and the interaction is usually positive (Bundy *et al*., 2004) [25]. The increase in grain yield might be due to the additive role of nitrogen and potassium as the availability of K fertilizer increases root growth which facilitates the absorption and transport of nitrate-N (NO^{3-}N) to the shoots of the plant and transports it later on to the aerial plant parts, which in turn increases the activities of N (Anjana *et al.*, 2009 and Hu *et al.*, 2016) [26, 27] hence improves vegetative growth, translocation of nutrients and enhances the supply of sucrose, promote the accumulation of starch in the grain and increases the grain yield of wheat (Tiwari, 2002., Liang and Yu 2004., Dekov, D. 2004) [20, 8]. Similar results were obtained by Singh and Lal, 2012, Lu *et al.* (2014) [19, 12], Akhter *et al.* (2017) [3-4]. It is concluded that a significant growth and yield response was observed with the application of potassium in 2 equal splits (50: 50). Among the nitrogen treatments, application of nitrogen in 3 splits with reduced basal dose (25: 50: 25) resulted in higher growth and yield as compared to the recommended practice.

Table 1: Plant height (cm) of wheat as influenced by split application of potassium and nitrogen

Treatments	Jointing		Boot stage		Anthesis		Milk stage		Dough		Maturity	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
K1	55.46	58.31	83.16	86.69	90.79	91.16	96.95	98.01	97.02	99.35	97.42	99.71
K2	60.13	61.84	90.80	94.34	98.97	100.32	105.57	106.15	105.94	106.81	106.34	107.16
K3	57.29	60.16	89.38	93.78	96.41	97.91	103.18	104.06	103.55	104.52	103.95	104.73
SEm±	0.76	0.68	0.40	0.35	1.44	0.45	2.70	0.58	1.98	0.48	1.50	0.50
CD (p=0.05)	2.22	2.01	1.54	1.25	4.48	1.75	6.25	1.96	5.81	1.70	4.72	1.96
N1	55.29	56.95	89.38	93.48	97.26	98.22	105.01	105.69	105.36	106.73	105.76	107.15
N2	59.54	61.62	87.12	91.20	94.53	95.12	99.95	100.92	100.05	101.54	100.45	101.94
N3	59.25	60.52	88.00	92.20	97.53	99.45	105.04	105.88	105.93	106.83	106.33	107.34
N4	57.46	60.67	87.11	90.23	93.71	94.68	99.35	100.36	99.68	101.31	100.08	101.09
N5	56.59	60.76	87.28	90.90	93.92	94.84	99.56	100.84	99.84	101.40	100.24	101.83
SEm±	1.03	0.71	0.52	0.96	1.06	0.73	1.55	0.73	1.53	1.03	1.40	0.73
CD (p=0.05)	3.00	2.08	1.51	2.8	3.11	2.13	4.52	2.12	4.47	3.03	4.10	2.11
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	

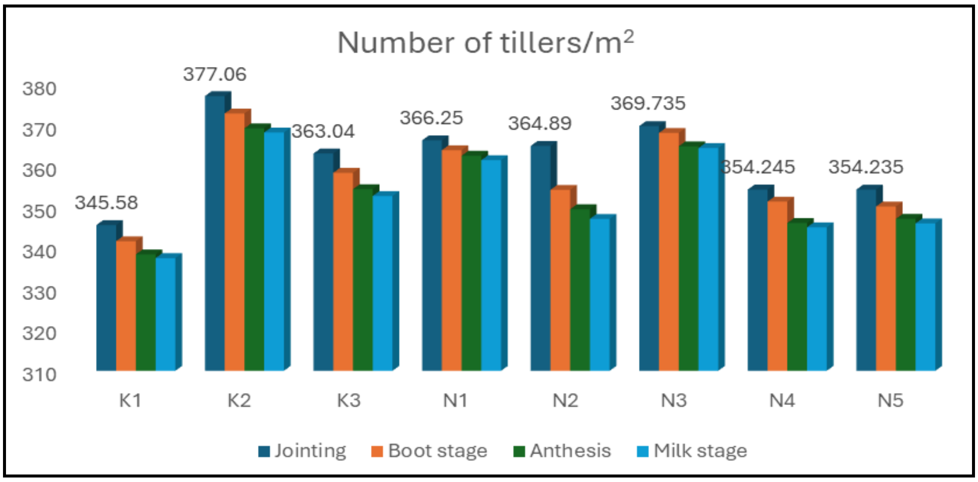

Fig 1: Periodic number of tillers m^{-2} as influenced by split application of nitrogen and potassium

Tale 2: Dry matter accumulation (q ha-1) at maturity as influenced by interaction between potassium and nitrogen splits in wheat crop

Treatments	2020-21					2021-22				
	N1	N2	N3	N4	N5	N1	N2	N3	N4	N5
K_1	101.71	101.13	106.06	104.92	99.81	119.01	118.71	122.92	122.84	118.13
K_2	109.53	108.93	110.24	105.82	109.20	129.53	128.93	130.24	128.80	129.20
K3	108.49	103.20	108.61	101.96	108.10	127.61	121.98	129.30	121.96	127.49
	SEm±		CD(p=0.05)			SEm±		CD(p=0.05)		
At same splits of potassium	0.74		2.15			0.75		2.20		
At same splits of nitrogen	0.84		2.75			0.87		2.90		

Table 3: Grain yield (q ha-1) as influenced by interaction between potassium and nitrogen splits in wheat crop

Treatments	2020-21					2021-22				
	N1	N2	N3	N4	N5	N1	N2	N3	N4	N5
K1	32.73	32.23	36.39	36.50	32.09	38.88	38.38	42.54	42.65	38.24
K2	41.63	34.55	43.39	33.30	37.19	48.97	41.89	50.73	40.64	44.53
K3	36.89	33.20	38.35	32.31	35.58	43.21	39.52	44.67	38.63	42.57
	SEm±		CD(p=0.05)		SEm±		CD(p=0.05)			
At same splits of potassium	1.22		3.56		1.19		3.47			
At same splits of nitrogen	1.23		3.81		1.10		3.32			

Conclusion

In conclusion, the split application of potassium and nitrogen had a significant impact on the growth attributes and grain yield of wheat. Notably, applying potassium in two equal splits (50:50) at basal and active tillering stages, along with nitrogen in three splits (25:50:25) at basal, active tillering, and booting stages, resulted in superior growth parameters and higher grain yield. This approach led to taller plants and increased tiller numbers, ultimately enhancing dry matter accumulation and grain yield. The interaction between potassium and nitrogen splits played a crucial role in optimizing nutrient uptake, promoting photosynthetic activity, and improving vegetative growth. These findings underscore the importance of tailored nutrient management practices for maximizing wheat productivity. Additionally, the study highlights the potential benefits of adopting split application strategies over conventional practices, contributing to sustainable crop production.

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