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Growth parameters and yield of wheat (*Triticum aestivum* L.) as influenced by varying levels of nitrogen, phosphorus and potassium

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Abstract
A Long term field experiment (37th crop cycle) was conducted at Agronomical Research farm of Birsa Agricultural University, Kanke, Ranchi during *Rabi* season in 2020-2021 to study the growth parameters and yield of wheat (*Triticum aestivum* L.) as influenced by varying levels of Nitrogen, Phosphorus and Potassium. The experiment was conducted in Partially Confounded Design with nineteen treatments replicated four times. The wheat variety used was HD 2967. Nitrogen, Phosphorus and potassium level used were 40, 80 and 120 kg N ha^{-1}, 0, 40 and 80 kg P_2O_5 ha^{-1} and 0 and 40 kg K_2O ha^{-1} respectively. Application of 120 kg N ha^{-1}, significantly improved plant height of wheat at all growth stages, produced maximum numbers of tillers at 60 DAS, 90 DAS and at harvest, recorded maximum dry matter accumulation at 90 DAS and at harvest and also enhanced leaf area index at 30, 60, 90 DAS and at harvest. Similarly, higher level of phosphorus i.e., of 80 kg P_2O_5 ha^{-1} significantly increased plant height, number of tillers, dry matter accumulation and leaf area index of wheat at all growth stages. Application of 40 kg K_2O ha^{-1} noted maximum plant height at 60 DAS, 90 DAS and at harvest. 40 kg K_2O ha^{-1} significantly influenced number of tillers as well as leaf area index and registered maximum values at all growth stages. But 40 kg K_2O ha^{-1} failed to cause significant variation in dry matter accumulation in wheat at all growth stages except at harvest. The maximum grain and straw yield of wheat was associated with application of 120 kg N ha^{-1}, 80 kg P kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1}.

Keywords: Growth parameters, yield, wheat, *Triticum aestivum* L., nitrogen, phosphorus, potassium

Introduction
Two of the most important environmental factors influencing the growth, metabolism and function of plants are soil fertility and mineral nutrition. Nitrogen, phosphorus and potassium are the three most abundantly acquired mineral elements by plants and they play vital roles in many aspect of plant metabolism (Bernstein *et al.* 2019) [1]. For growth and development, plants need macronutrients nitrogen, phosphorus and potassium. These nutrients have a significant impact on crop yield and quality in agricultural production (Wang *et al.* 2021) [2]. Boosting crop yield through proper and balanced fertilizer application stands as a crucial aspect for effective crop management. However, the increasing use of imbalanced and indiscriminate use of chemical fertilizers leads to deterioration in soil health and fertility. The majority of cereal growing regions are currently under threat from problems like resource degradation, declining productivity, escalating input cost and diminishing return. But in order to feed the world's growing population which is growing at a rate of 1.8% each year, our countries must achieve higher production (Chatterjee *et al.* 2016) [3].
Wheat is a staple crop in many countries and hence its consumption is directly proportional to the population growth (Ramdas *et al.* 2012) [4]. In India wheat has been under cultivation in about 30 million hectares (14% of global area) with average productivity of 3371 kg/ha (Ramdas *et al.* 2019) [5]. Fertility management is a crucial factor in maximizing the productivity of wheat because wheat crop is highly responsive to applied nutrients. The stagnant situation in fertilizer consumption and higher negative balance are posing a threat to soil fertility and sustainable

agriculture production (Kumar and Agarwal 2013) [6].
It is, therefore necessary to replenish the soil with balanced fertilization for obtaining higher yield beside maintaining the sustainability of the system. Balanced fertilization is the application of essential nutrients particularly major nutrients N,P and K in right proportion and in optimum quantity through correct method and time of application, suited for specific soil-crop and climatic situation. Hence, the study focuses on the growth parameters and yield of wheat (*Triticum aestivum* L.) as influenced by varying levels of nitrogen, phosphorus and potassium.

Materials and Methods
A long term (37 year) field experiment was conducted at Agronomical Research farm of Birsa Agricultural University, Kanke, Ranchi during *Rabi* season in 2020-21. The experimental plot was a medium land having well drained soil and uniform topography. The soil was sandy loam in texture with bulk density 1.54 Mgm^{-3} and good water retention (FC 21.5% and PWP 11.36%) and water holding capacity (38.7%) was also observed in soil. Soil reaction was acidic in nature with low available N and P, medium in available K. The experiment was conducted in Partially Confounded Design with nineteen treatments replicated four times. The wheat variety used was HD 2967. Nitrogen, Phosphorus and Potassium level used were 40, 80 and 120 kg N ha^{-1}, 0, 40 and 80 kg P_2O_5 ha^{-1} and 0 and 40 kg K_2O ha^{-1} respectively. The inorganic source of Nitrogen (N), Phosphorus (P) and Potassium (K) were applied through urea, Diammonium phosphate and muriate of potash as per treatment. The full dose of P and K along with one third of N were applied at the time of sowing and remaining N in 2 equal splits top dressed as per treatment at 30 and 60 DAS. The data on growth parameter were recorded at 30, 60, 90 DAS and at harvest.

Discussion
Data presented in Table 1 and 2 showed that fertility levels had significant effect on plant height at all the stages of crop growth. The plant height, number of tillers, dry matter accumulation and leaf area index increased with advancement in crop age irrespective of treatments.

Effect of growth parameters
Effect of nitrogen: The result of the investigation presented in Table 1. showed significant improvement in plant height at all growth stages and were observed with application of 120 kg N ha^{-1} which recorded tallest plant at all growth stages and was statistically superior to other nitrogen levels except at 30 DAS where N_{120} kg ha^{-1} was comparable to N_{80} kg ha^{-1}. Increased nitrogen availability increases plant height by increasing cell number and cell elongation since nitrogen is one of the primary and vital nutrients needed for plant growth and development (Bloom, 2015) [7]. These results agree with those reported by Dawar *et al.* (2023) [8].
Similarly maximum numbers of tillers was associated with application of 120 kg N ha^{-1} which was 39.05%, 24.81%, and 92.31% more over control at 60, 90 DAS and at harvest respectively but remained at par with 80 kg N ha^{-1} at 90 DAS and harvest. The nitrogen is the key component of cellular biomolecules such as nucleic nucleic acids, proteins, chlorophyll and plant growth regulators (Nguyen *et al*. 2015) [9]. Nitrogen application promotes cytokinin biosynthesis and inhibits its degradation, thereby inducing tiller bud development and also affects auxin transport and strigolactone synthesis to regulate auxillary bud activation (Yang *et al*.2019) [10]. Significant increase in number of tillers with application of 120 kg N ha^{-1} in wheat was also reported by Singh *et al.* (2018a) [11].
Furthermore, fertility rate of nitrogen 120 kg ha^{-1} registered maximum dry matter accumulation at all growth stages but it failed to cause significant variation in dry matter accumulation during 30 DAS and 60 DAS. During 90 DAS and at harvest dry matter accumulation in wheat was found maximum with application of 120 kg N ha^{-1} which was statistically superior over other nitrogen levels. Effect of higher N levels i.e, 120 kg N ha^{-1} significantly improved leaf area index and exerted is superiority over its respective lower nitrogen levels at all growth stages except 30 DAS where 120 kg N ha^{-1} remained at par with N_{80} kg ha^{-1}. Allen and Morgan, (1972) [12] reported that increase in nitrogen fertilizer improved LAI due to enhanced availability of nitrogen resulting in more leaf area resulting in higher photo assimilate and thereby increasing dry matter accumulation. This result is in close conformity with Alemu (2018) [13].

Effect of phosphorus: Application of 80 kg P_2O_5 ha^{-1} enhanced plant height, number of tillers, dry matter accumulation and leaf area index at all growth stages. Application of 80 kg P_2O_5 ha^{-1} increased plant height by 112.96%, 124.65%, 53.48% and 43.44% over control at 30, 60, 90 DAS and at harvest respectively. Tallest plant under the treatments was mainly due to rapid growth caused by maintenance of adequate nutrient supply to crops which maintained good establishment of the roots and various metabolic process which performed higher nutrient mobilization and uptake which contributed to rapid cell division cell elongation and thus resulted in higher plant height (Singh *et al*. 2018) [14].
Higher level of Phosphorus fertility level showed significant higher tillers numbers at 30, 60, and at harvest and was statistically superior over rest of the treatments. Similarly 80 kg P_2O_5 ha^{-1} significantly improved dry matter accumulation in wheat at 60, 90 DAS and at harvest but remained comparable 40 kg P_2O_5 ha^{-1} at 30 DAS. 80 kg P_2O_5 ha^{-1} significantly increased leaf area index and was statistically superior over other phosphorus levels. A higher availability of phosphorus facilitates the growth of new cells, increases plant vigor and improves nitrogen utilization. The energy gained from photosynthesis, enzyme activation/inactivation and carbohydrates metabolism stored in storage compound (ATP and ADP) for later use might have resulted in vigorous growth of plants (Kumawat *et al.* 2021) [15]. It is reported that when phosphorus is limiting, the most striking effects are a reduction in leaf expansion and leaf surface are, as well as the number of leaves. Shoot growth is more affected than root growth, which leads to decrease in the shoot root dry weight ratio. Nonetheless, root growth is also reduced by phosphorus deficiency, leading to less root mass to reach water and nutrients (Anonymous 1999) [16]. Nikhil *et al.* (2021) [17] and Mumtaz *et al*. (2014) [18] also described the increase in plant height, number of tillers, leaf area index as well as dry matter accumulation with the increasing phosphorus application rate.

Effect of potassium
The potassium fertility levels significantly influenced growth parameters and maximum plant height, number of tillers, dry matter accumulation as well as leaf area index and maximum values were associated with application of 40 kg K_2O ha^{-1}. Plant height increased by 105.85%, 42.51% and 36.29% at 60, 90 DAS and at harvest. Application of 40 kg K_2O ha^{-1} significantly improved number of tillers at all growth stages which expressed its superiority over 0 kg K_2O ha^{-1} control except at 30 DAS.

Similarly, dry matter accumulation also improved with application of 40 kg K_2O ha^{-1} and recorded maximum dry mater (35.13, 203.58, 626.61 and 800.45 g m^{-2} at 30, 60, 90 DAS and at harvest respectively) but failed to exert superiority over other treatments at all growth stages except at harvest. Furthermore, leaf area index increased by application of 40 kg K_2O ha^{-1} which exhibited it superiority over 0 kg K_2O ha^{-1} at 30 DAS as well as at 60 DAS. Similar response was response was also recorded by Tomar *et al.* (2020) [19]. Bahmanyar and Ranjbar (2008) [20] suggested that potassium has favourable influence on metabolic and biological activities and stimulating photosynthetic pigments and enzyme activity, these effects encourages vegetative growth in plant. Hence supply of adequate potassium levels might have resulted in better growth and development in plant.

Table 1: Effect of Nitrogen, Phosphorus and Potassium on plant height and tillers of Wheat

Fertilizer level	Plant height (cm)				Tillers (m^{-2})			
	30	60	90	Harvest	30	60	90	Harvest
N_{40}	18.18	70.08	79.84	88.05	93.83	367.67	320.96	303.04
N_{80}	19.84	73.34	82.02	89.29	97.82	389.50	331.50	323.25
N_{120}	20.34	77.63	87.43	95.10	99.61	414.38	356.96	346.17
SEm±	0.35	1.40	1.66	1.92	2.02	7.51	6.44	5.82
CD at 5%	0.98	3.98	4.72	5.46	NS	21.30	18.27	16.50
P level								
P_0	12.45	60.48	69.17	77.23	90.21	315.38	280.08	266.08
P_{40}	22.58	78.14	87.35	95.30	97.59	416.58	351.67	343.75
P_{80}	23.32	82.45	92.78	99.91	103.45	439.58	377.67	362.63
SEm±	0.35	1.40	1.66	1.92	2.02	7.51	6.44	5.82
CD at 5%	0.98	3.98	4.72	5.46	5.73	21.30	18.27	16.50
K Level								
K_0	19.11	71.81	80.05	86.69	94.75	376.06	323.36	314.44
K_{40}	19.79	75.56	86.15	94.93	99.42	404.97	349.58	333.86
SEm±	0.28	1.15	1.36	1.57	1.65	6.13	5.26	4.75
CD at 5%	NS	3.25	3.85	4.46	4.68	17.39	14.92	13.47
Control	10.95	36.70	60.45	69.65	77.46	298.00	286.00	180.00
CV%	9.29	10.05	10.20	10.74	10.49	9.75	9.58	9.38

Effect on grain and straw yield

Effect of nitrogen

Higher nitrogen levels significantly influenced the grain and straw yield of wheat. Application of 120 kg N ha^1 recorded maximum grain and straw yield which was statistically superior over other nitrogen rates. Of all vital nutrients given to the plant, nitrogen is the most important one since it plays a crucial part in the process of photosynthesis. More nitrogen supplied resulted in a higher rate of photosynthesis and a higher yield since produced significant amount of dry matter and more assimilates that were transported to fill the seeds (Kumar *et al.* 2023) [21]. The more grain yield and straw production was recorded with increased levels of nitrogen (120 kg ha^{-1}) was also reported by Mukherjee (2008) [22].

Effect of phosphorus

Data presented in Table 2. showed that the application of phosphorus @ 80 kg ha^{-1} recorded significantly higher grain and straw yield compared to its respective lower levels of phosphorus. The application of 80 kg P_2O_5 ha^{-1} increased grain and straw yield by 200.76% and 150.93% over control and exhibited its superiority over other phosphorus levels. The higher yield under higher phosphorus levels may have resulted from adequate nutrient availability which contributed to increased dry matter production, higher yield attributes and thus led to the higher yield under the treatment. Reduced phosphorus dose of 0 kg ha^{-1} produced lowest yield due to poor growth, metabolic process and yield attributes (Singh *et al*. 2018b)[23]. The phosphorus application is attributed to source and sink relationship which resulted in increase in grain yield. The translocation of photosynthates from source to sink may have resulted in high seed yield. Phosphorus increases yield due to its well developed root system, increased in N fixation and its availability to plants and the favorable environments in the rhizosphere (Akram *et al*. 2022) [24]. Straw yield is dependent on vegetative growth and application of balanced and optimum levels of phosphorus contributed to improved plant height, tillers, dry matter accumulation and leaf area ultimately resulting in higher straw yield. Kumar *et al*. (2018) [25] also reported that crop yield improved considerably with application of 80 kg P_2O_5 ha^{-1} which was further improved with balance use of Nitrogen and Potassium.

Effect of potassium: Data on potassium presented in Table 2. revealed that increased fertility levels of potassium significantly influenced the grain and straw yield of wheat. Potassium @ 40 kg ha^{-1} significantly increased the grain and straw yield and exerted its superiority over other treatments. Similar results were report by Chauhan (2014) [26]. Potassium regulates the opening and closing of stomata and improves the photosynthesis by regulating the absorption of CO_2. It plays crucial role in the photosynthesis and the resulting translocation and metabolism of carbohydrates which ultimately increases crop yield and improves grain quality (Rawat *et al*. 2022) [27].

Table 2: Effect of Nitrogen, Phosphorus and Potassium on dry matter accumulation, LAI and yield of Wheat

Fertlizer level	Dry matter accumulation (g m^{-2})				Leaf area index			Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
	30	60	90	harvest	30	60	90		
N Level									
N_{40}	34.25	193.52	578.02	716.78	0.62	2.28	2.58	28.57	44.72
N_{80}	34.94	202.00	616.43	770.96	0.71	2.48	2.78	33.46	51.05
N_{120}	35.51	206.69	650.63	823.06	0.74	2.64	3.04	35.67	53.74
SEm±	0.76	4.41	10.76	13.83	0.01	0.04	0.05	0.63	0.94
CD at 5%	NS	NS	30.52	39.24	0.04	0.12	0.14	1.79	2.67
P Level									
P_0	30.06	160.00	455.48	546.78	0.47	1.77	1.98	19.52	34.17
P_{40}	36.70	214.27	665.64	842.62	0.76	2.69	3.02	37.08	55.17
P_{80}	37.93	227.94	723.95	921.41	0.83	2.94	3.40	41.10	60.17
SEm±	0.76	4.41	10.76	13.83	0.01	0.04	0.05	0.63	0.94
CD at 5%	2.16	12.51	30.52	39.24	0.04	0.12	0.14	1.79	2.67
K Level									
K_0	34.67	197.89	603.44	740.09	0.67	2.39	2.77	31.57	48.70
K_{40}	35.13	203.58	626.61	800.45	0.71	2.54	2.83	33.56	50.97
SEm±	0.62	3.60	8.78	11.29	0.01	0.03	0.04	0.52	0.77
CD at 5%	NS	NS	NS	32.04	0.03	0.10	0.11	1.46	2.18
Control	16.81	81.09	200.49	240.49	0.30	1.39	0.51	13.67	23.98
CV%	11.52	11.76	9.48	9.76	10.58	8.80	8.98	10.36	9.98

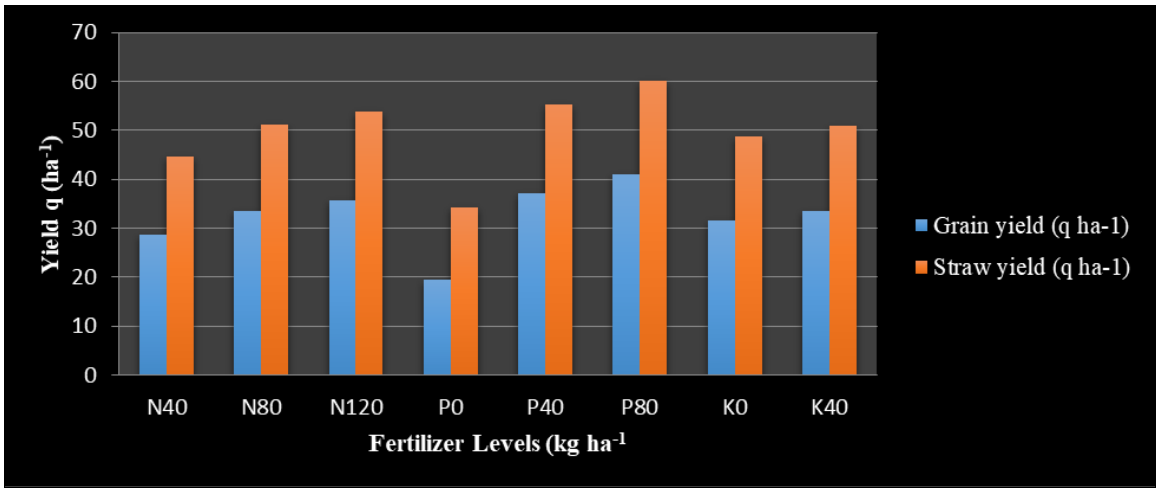

Fig 1: Grain yield and straw yield of wheat as influenced by varying levels of nitrogen, phosphorus and potassium

Conclusion

Thus, taking the findings of the present study into consideration, it may be concluded that higher fertilizer rates of Nitrogen, Phosphorus and Potassium i.e., 120 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} resulted in maximum plant height, number of tillers, dry matter accumulation and leaf area index at all growth stages. Fertility level of 120 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} produced highest grain and straw yield ha^{-1}. This study indicated that higher rate of fertilizer contributed towards better vegetative growth and yield mainly due to higher absorption of nutrients which increased phostosynthates accumulation, better metabolic activity and high biomass production compared to their respective low levels of fertilizers.

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