Indian Journal of Agricultural Sciences **93** (5): 506–511, May 2023/Article
https://doi.org/10.56093/ijas.v93i5.132398

Integrated nutrient management prescription for late-sown wheat (*Triticum aestivum*)

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Received: 18 January 2023; Accepted: 19 April 2023

ABSTRACT

Integrated nutrient management prescription was developed for late-sown variety of wheat (*Triticum aestivum* L.) (HD 3059) through soil test based crop response study. A field experiment was conducted at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi during winter (*rabi*) season of 2020–21 and 2021–22 to develop the integrated nutrient management prescription for late-sown wheat. Experiment was laid out in factorial randomized block design with 24 treatments having 3 levels of each N (60,120,180 kg/ha), P_2O_5 (30, 60, 90 kg/ha) and K_2O (20, 40, 60 kg/ha). The basic parameters, viz. nutrient requirement (NR), percentage contribution of nutrients from soil (CS); fertilizer (CF) and farmyard manure (FYM) (CFYM) were quantified. Fertilizer prescription equations in integration with FYM were developed from the data obtained in the study. In order to produce 100 kg of late-sown wheat, the amount of major nutrients needed were 2.24 and 2.27, 0.45 and 0.47, 1.89 and 1.92 kg of nitrogen (N), phosphorus (P) and potassium (K) during 2020–21 and 2021–22, respectively. Phosphorus as soil nutrient contributed the maximum towards crop production; while the contribution of K from fertilizer (118.38 and 125.03) was highest for both seasons. Contribution of N from fertilizer (50.05, 51.38) was more than that of soil (33.81, 33.65). However, contribution of all the nutrients from FYM was lower. The equations developed were used to formulate ready reckoner for a range of soil test values to get a yield target of 55 q/ha for late-sown wheat. Nutrient management of late-sown wheat involving inorganic fertilizer in integration with FYM (10 t/ha) was prescribed through the ready reckoner. The study suggests that the excessive amount of fertilizer consumption as well as the subsequent adverse effect on the environment can be curtailed if FYM is used in combination with inorganic fertilizer.

Keywords: Farmyard manure, Fertilizer, Integrated nutrient management, Late-sown wheat, Targeted yield

Wheat (*Triticum aestivum* L.) provides food and nutritional security to 36% of the global population (Sharma and Jain 2014). It symbolizes green revolution in India as it made the country self-sufficient in food production. Globally, India ranks second in production and exported 2.05 Mt of wheat during 2020–21, earning $549.70M (Madhukar *et al.* 2022, APEDA 2022). Rice-wheat cropping sequence is the world's largest production system, occupying an area of about 9.2 Mha in India (Dhanda *et al.* 2022). Major reason for late sowing of wheat is the availability of narrow window between rice harvesting and wheat sowing. Harvesting of other preceding crops in intensive agricultural production system also delays wheat sowing (Gupta *et al.* 2002). Sub-optimal temperature during germination and early stages of growth causes poor crop stand in late-sown wheat. The quick temperature rise at reproductive stage, reduces photosynthetic efficiency, accelerates crop senescence, shortens grain filling duration, reduces harvest index and crop yield (McDonald *et al.* 2022). To compensate yield penalty, HD 3059 is a suitable late-sown variety (Singh *et al.* 2014) due to its specific characteristics.

Lack of synchrony between added nutrients and their uptake by crops reduces nutrient use efficiency and crop production, besides polluting environment (Liu *et al.* 2011). Therefore, the recommendation should consider contribution of nutrients from soil (CS), fertilizer (CF) and organic amendments if any along with crop nutrient demand. Chemical fertilizers integrated with organic input improves soil health, sustains the environment and decreases fertilizer import load of the country (Moe *et al.* 2019). Hence, the study was undertaken with an objective to develop soil-test based fertilizer recommendations of N, P and K in integration with FYM for targeted yield of late-sown wheat through soil test crop response (STCR) approach, which would be used to generate a ready reckoner for a range of soil test values.

MATERIALS AND METHODS

The field experiment was conducted at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi (77°1´E, 28°4´ E and 229 above MSL) during winter

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(*rabi*) season of 2020–21 and 2021–22. The mean minimum and maximum temperatures showed wide variations being 22°C and 41°C in summer and 5°C and 23°C in winter, respectively during period of experiment. Average annual precipitation was about 948.9 mm in 2020 and 1781.4 mm in 2021. Out of total annual rainfall, more than 80% is normally received during June to September; however approximately 5% of it is received in January.

The soil is alluvial, sandy loam in texture, alkaline in reaction and free from salinity, occurring on nearly level to very gently sloping land. Clay mineralogy is dominated by illite along with presence of kaolinite, chlorite and montmorillonite. Taxonomically it belongs to Typic Haplustept sub-group. To conduct the experiment, three artificial fertility gradients (low, strip-I; medium, strip II and high, strip-III) were created using inductive methodology by Ramamoorthy *et al.* (1967). For this, experimental field was divided into three rectangular strips by applying graded doses of fertilizer N, P and K in the ratio of $N_0P_0K_0$ in strip-I, $N_{½}P_{½}K_{½}$ in strip-II and $N_1P_1K_1$ in strip-III, where $N_1P_1K_1$ represents 400, 300 and 300 kg N, P and K/ha, respectively. Soil fertility gradient with respect to FYM was also developed by applying 0, 5 and 10 t/ha in each strip across the fertility gradient (Pandey *et al.* 2019). This resulted in development of nine distinct fertility blocks (three in each of the three strips). In order to stabilize the artificially created fertility gradient, an exhaustive crop (fodder maize; variety: African tall) was taken.

After harvesting the exhaustive crop, test crop (late-sown wheat) was taken in winter. The whole experiment was laid out in factorial randomized block design. The treatments consisted of selective combinations of three levels of nitrogen (60, 120 and 180 kg N/ha), phosphorus (30, 60 and 90 kg P_2O_5/ha) and potassium (20, 40 and 60 kg K_2O/ha) for late-sown wheat. Total 24 treatments were accommodated in each strip (8 treatments randomized in each block including 1 control). Thus total 72 plots were made for the experiment.

Before sowing of the test crop, FYM (containing 0.4, 0.2 and 0.5% of N, P and K, respectively) was applied in the field and mixed thoroughly. The variety HD-3059 was sown using seed drill on 28th December of 2020 and 30th November 2021 and the harvesting was done on 4th May 2021 and 7th April 2022, respectively. The basal dose of fertilizer consisting of full dose of phosphorus, potassium and 1/3rd dose of nitrogen was applied in the evening to avoid volatilization loss. Other two split doses of nitrogen (1/3rd each) were applied after first irrigation at crown root initiation and at maximum tillering stage following second irrigation. Other cultural operations including pest and weed control were carried out as per need by adopting standard agronomic norms. Plot-wise harvesting was done at maturity and straw and grain yields were recorded.

Soil (0–15 cm depth), grain and straw samples were collected from all the 72 plots using standard procedure. After processing of soil samples, analysis of available N, P and K was done using standard methodology given by Subbaiah and Asija (1956), Olsen *et al.* (1954) and Hanway and Heidal (1952), respectively. Standard methodology by Jackson (1974) was used for analysis of plant samples including grain and straw. The computation of crop nutrient uptake was done using yield data and nutrient concentration in straw and grain samples.

The following equations were used for calculation of basic parameters:

$$\text{NR (kg/q)} = \frac{\text{Total uptake of nutrient (kg/ha)}}{\text{Grain yield (q/ha)}} \quad (1)$$

$$\text{CS (\%)} = \frac{\text{Total uptake of nutrient in control plot (kg/ha)}}{\text{STV of given nutrient in control plot (kg/ha)}} \times 100 \quad (2)$$

$$\text{CF (\%)} = \frac{\text{Total uptake of nutrient in fertilized plot (kg/ha)} - [\text{STV of nutrient in fertilized plot (kg/ha)} \times \text{\% CS/100}]}{\text{Fertilizer nutrient applied (kg/ha)}} \times 100 \quad (3)$$

$$\text{CFYM (\%)} = \frac{\text{Total uptake of nutrient from control plot with FYM (kg/ha)} - [\text{STV of control plot with FYM (kg/ha)} \times \text{\% CS/100}]}{\text{Total nutrient applied through farmyard manure (kg/ha)}} \times 100 \quad (4)$$

For development of fertilizer prescription equations, the formulas used are as follows:

$$\text{FN} = \frac{\text{NR}}{\text{CF/100}}\text{T} - \frac{\text{CS}}{\text{CF}}\text{STVN} - \frac{\text{CFYM}}{\text{CF}}\text{FYMN} \quad (5)$$

$$\text{FP} = \frac{\text{NR}}{\text{CF/100}}\text{T} - \frac{\text{CS}}{\text{CF}}\text{STVP} - \frac{\text{CFYM}}{\text{CF}}\text{FYMP} \quad (6)$$

$$\text{FK} = \frac{\text{NR}}{\text{CF/100}}\text{T} - \frac{\text{CS}}{\text{CF}}\text{STVK} - \frac{\text{CFYM}}{\text{CF}}\text{FYMK} \quad (7)$$

where FN, FP and FK represent fertilizer N, P and K (kg/ha) respectively; NR, nutrient requirement of N, P and K (kg/q); CS, CF and CFYM represent the percentage of nutrients contributed from soil, fertilizer and FYM, respectively; The soil test values of available N, P and K (kg/ha) are denoted as STVN, STVP and STVK, respectively. The amount of N, P and K applied through FYM are represented as: FYMN, FYMP and FYMK while T represents target yield (kg/ha) of crop.

RESULTS AND DISCUSSION

Initial soil nutrient status of plough layer (0–15 cm) is presented in Table 1. The mean available N values were recorded lowest in strip-I in both the seasons (195.40, 164.06 kg/ha) followed by strip-II (200.73, 184.73 kg/ha) and strip-III (214.51, 192.21 kg/ha). The recorded values of available P were 24.60, 31.08 and 32.15 kg/ha in 2020 and 22.72, 28.60 and 27.72 kg/ha in 2021 in strip I, II and III, respectively. Average values of NH_4OAc-K were 183.59, 195.05, and 210.62 kg/ha in 2020–21 whereas in 2021–22 the mean values were 168.69, 177.79 and 190.15 kg/ha in strip having low, medium and high fertility status, respectively. The highest values of all the available major nutrient were recorded in strip III, followed by strip-II and the least values were observed in strip-I because of the artificial fertility gradient created using graded doses of fertilizers in the respective fields. Similar findings have been reported by Santhi *et al.* (2002), Chatterjee *et al.* (2010) and Basumatary *et al.* (2015). The CV values are indicative of the variations observed within the strips. Higher degree of dispersion around the mean values of available P was observed in both seasons (Table 1). Higher CV values for Olsen's-P indicated larger variation in P content as compared to N and K in the experimental plots. This could be attributed to the substantial accumulation of applied P as residual due to low P uptake efficiency (10–20%) as reported by Mahajan *et al.* (2013). Graded doses of chemical fertilization and FYM application resulted in development of marked fertility gradient across the field before sowing of late-sown wheat (Table 1)

The data of grain yield and crop nutrient uptake are presented in Table 1. In both the seasons, maximum grain yield was recorded in the highest fertility strip followed by medium fertility strip and low fertility strip due to variations in nutrient availability of those strips. The average grain yield of overall plots representing strip-I, strip-II and strip-III were 47.66, 48.64 and 50.04 and 47.22, 47.77 and 50.06 q/ha during 2020–21 and 2021–22, respectively. With increasing fertilizer dose and FYM, the yield increased in

Table 1 Initial nutrients profile of plough layer (kg/ha) soil and late-sown wheat grain yield (q/ha) and crop nutrient uptake (kg/ha) as affected by soil nutrient status

Nutrient	Strip-I		Strip-II		Strip-III	
	Range	Mean ± SD (CV)	Range	Mean ± SD (CV)	Range	Mean ± SD (CV)
2020–21						
Alkaline $KMnO_4$-N	183.08-220.29	195.40±9.65 (4.94)	189.08-219.60	200.73±8.32 (4.17)	182-229.30	214.51±9.95 (4.66)
Olsen's-P	17.54-31	24.60±3.92 (15.90)	14-41.84	31.08±6.50 (21.10)	17.10-46.64	32.15±8.78 (27.05)
NH_4OAc-K	163.50-204.43	183.59±11.90 (6.48)	171.20-218.77	195.05±15.16 (7.70)	182.29-232.80	210.62±14.06 (6.68)
Grain yield	39.10-52.86	47.66±3.83 (8.04)	39.56-53.32	48.64±3.92 (8.06)	42.54-55.21	50.04±3.44 (6.57)
N uptake	54-133	108.16±21.41 (19.79)	56-139	107.79±21.81 (20.24)	60.143	114.63±22.03 (19.22)
P uptake	10-29	19.19±4.71 (24.56)	7-33	25±6.47 (25.88)	8.45-36.22	22.99±7.55 (32.85)
K uptake	53.15-106	84.23±13.93 (16.54)	55.41-122.90	94.71±18.21 (19.13)	61.05-137.71	99.84±19.93 (19.96)
2021-22						
Alkaline $KMnO_4$-N	153-179.38	164.06±9.10 (5.54)	173.08-203.60	184.73±8.32 (4.50)	159-212.32	192.21±8.21 (4.68)
Olsen's-P	13-27	22.72±3.82 (16.79)	18.95-38.34	28.60±5.31 (18.58)	14.33-41.54	27.92±8.54 (30.60)
NH_4OAc-K	155-193.27	168.69±11.90 (7.06)	153.50-203.77	177.79±18.16 (9.06)	170.25-215.05	190.15±15.55 (6.89)
Grain yield	37.02-52.17	47.22±3.90 (8.26)	35.01-52.85	47.77±4.86 (10.17)	40.14-55.71	50.06±3.80 (7.60)
N uptake	53.09-132.15	108.98±21.45 (19.68)	52.33-142.59	107.76±22.63 (21)	60.01-143.61	115.65±22.15 (19.15)
P uptake	9.99-29.98	19.52±4.74 (24.31)	8.23-35.08	25.28±6.87 (27.18)	7.82-37.08	23.71±7.67 (32.35)
K uptake	52.05-106.44	84.50±14.02 (16.59)	54.91-122.90	94.74±18.58 (19.61)	61.20-139.59	100.70±19.94 (19.80)

SD, standard deviation; CV (coefficient of variation in %) = (SD/Mean*100) the strips. The higher nutrient uptake in strip having greater nutrient content might have positive impact on crop growth and development, which resulted in maximum grain yield in strip-III, which was 3 and 5% higher than strip-II and strip-I, respectively. The maximum grain yield of 50.04 and 50.06 q/ha was recorded in strip-III during first and second season, respectively with application of 180, 90 and 60 kg/ha of N, P_2O_5 and K_2O in combination with 10 t/ha FYM. It was also observed that the maximum amount of major nutrients were taken up by crop in strip-III, whereas least crop nutrient uptake was observed in strip-I during both the years. The fertility status of soil had direct bearing on crop nutrient uptake which is visible from the data (Table 2). The variability in case of crop nutrient uptake within each strip was even higher when compared with soil nutrient status with respect to N, P and K, which is indicated by higher value of CV. Variability in nutrient uptake between the strips might be due to nutrient transport mechanisms involved in case of soils, where nutrient concentrations are either limiting, adequate or excess.

The amount of N, P and K required to produce 100 kg of late-sown wheat is depicted Table 2. As the NR value depends on total nutrient uptake, lesser amount of P was required to produce 100 kg of wheat when compared with N and K. Similar nutrient requirement values were observed in case of wheat through QUEFTS approach (Chuan *et al.* 2013). However, the per cent contribution of N, P and K to the total uptake of nutrients by wheat crop from various nutrient sources varied significantly in the crop growing seasons (Table 2). Contribution of N from soil available nutrient pool (CS), fertilizer (CF) and farmyard manure (CFYM) were 33.8, 50.05 and 6.84% in the year 2020–21 and 33.65, 51.38 and 12.63%, respectively in 2021–22. For P, the values of CS, CF and CFYM in 2020–21 were 61.76, 29.37, 11.12% and 63.06, 30.62 and 8.68% during 2021–22, respectively. Likewise, the contribution of K from different sources, viz. CS, CF and CFYM was found to be 35.34, 118.38 and 2.77% in 2020–21 and 35.54, 125.03 and 7.65% in 2021–22, respectively. Among the nutrients, majority of P was supplied from soil while K was mostly available from chemical fertilizer. Therefore, while prescribing fertilizer for P, care must be taken to include the soil's supplying capacity of P and crop response. Native P has an important role to play in providing P to crop. Higher contribution of N from fertilizer was due to split application that met the crop demand during peak requirement of N. Potassium applied through fertilizers become easily available to the crop which is indicated by higher CF value of K.

The fertilizer prescription equations developed to get targeted yield of late-sown wheat variety HD-3059 using the basic parameters are given as:

2020–21; NPK alone; FN=4.48 T – 0.68 STVN; FP =1.55 T – 2.10 STVP; FK= 1.60 T – 0.30 STVK; NPK + FYM; FN = 4.48 T – 0.68 STVN – 0.14FYMN; FP =1.55 T – 2.10 STVP – 0.38 FYMP; FK = 1.60 T- 0.30 STVK – 0.02 FYMK

2021–22; NPK alone; FN =4.43 T – 0.65 STVN; FP =1.52 T – 2.06 STVP; FK =1.54 T- 0.28 STVK; NPK + FYM; FN =4.43 T – 0.65 STVN – 0.25 FYMN; FP =1.52 T –2.06 STVP– 0.28 FYMP; FK =1.54 T- 0.28 STVK – 0.06 FYMK

where FN, FP and FK: amount of N, P and K (kg/ha) fertilizer, respectively; STVN, STVP and STVK: soil test value of available N, P and K (kg/ha), respectively; FYMN, FYMP and FYMK: amount of N, P and K applied through FYM, respectively; T: Targeted yield (kg/ha) of late-sown wheat grain.

Table 2 Basic parameters for calculating fertilizer requirement, with and without FYM, for the targeted yield of late-sown wheat

Basic parameter	2020–21			2021–22		
	N	P	K	N	P	K
Nutrient requirement (kg/q)	2.24	0.45	1.89	2.27	0.47	1.92
Contribution of nutrient from soil (CS) (%)	33.81	61.76	35.34	33.65	63.06	35.54
Contribution of nutrient from fertilizer (CF) (%)	50.05	29.37	1118.38	51.38	30.62	125.03
Contribution of nutrient from FYM (CFYM) (%)	6.81	11.12	2.77	12.63	8.68	7.65

The amount of fertilizer needed with or without the inclusion of FYM (10 t/ha) to get a targeted yield of 55 q/ha of late-sown wheat for a range of soil test values for major nutrients is presented in Fig 1 a, b, c for both the wheat growing seasons. The figure clearly indicates that the integration of 10 t FYM/ha for different soil test values brings a significant reduction in the need for chemical fertilizers to get 55 q/ha of grain yield. However, the contribution of FYM to supply nutrient was found to be low as FYM being bulky in nature and the concentration of major nutrient in it is very low. But FYM is required to improve soil physical properties and stimulate microorganisms to provide favourable condition for nutrient acquisition and crop growth. For achieving the targeted grain yield (55 q/ha) in a field having soil test values of 200.0 kg $KMnO_4$-N, 20.0 kg Olsen's-P and 200.0 kg NH_4OAc-K/ha, the fertilizer N, P_2O_5 and K_2O required were 114.5, 43.1 and 28.3 kg/ha, respectively without integration of FYM (Fig 1 a,b,c). However, with addition of FYM at the rate of 10 t/ha (containing 0.4, 0.2 and 0.5% of N, P and K, respectively) along with NPK, the fertilizer requirement was reduced to 106.0 N, 35.5 P_2O_5 and 27.1 K_2O kg/ha. However, validation trial in farmers field is desirable before recommending the fertilizer prescriptions to be used in given agro-climatic region using the particular varity to get desirable yield. In place of FYM, other organic amendment can also be included in the fertilizer prescription depending on the availability of locally available resource(s) with the farmer. In the present

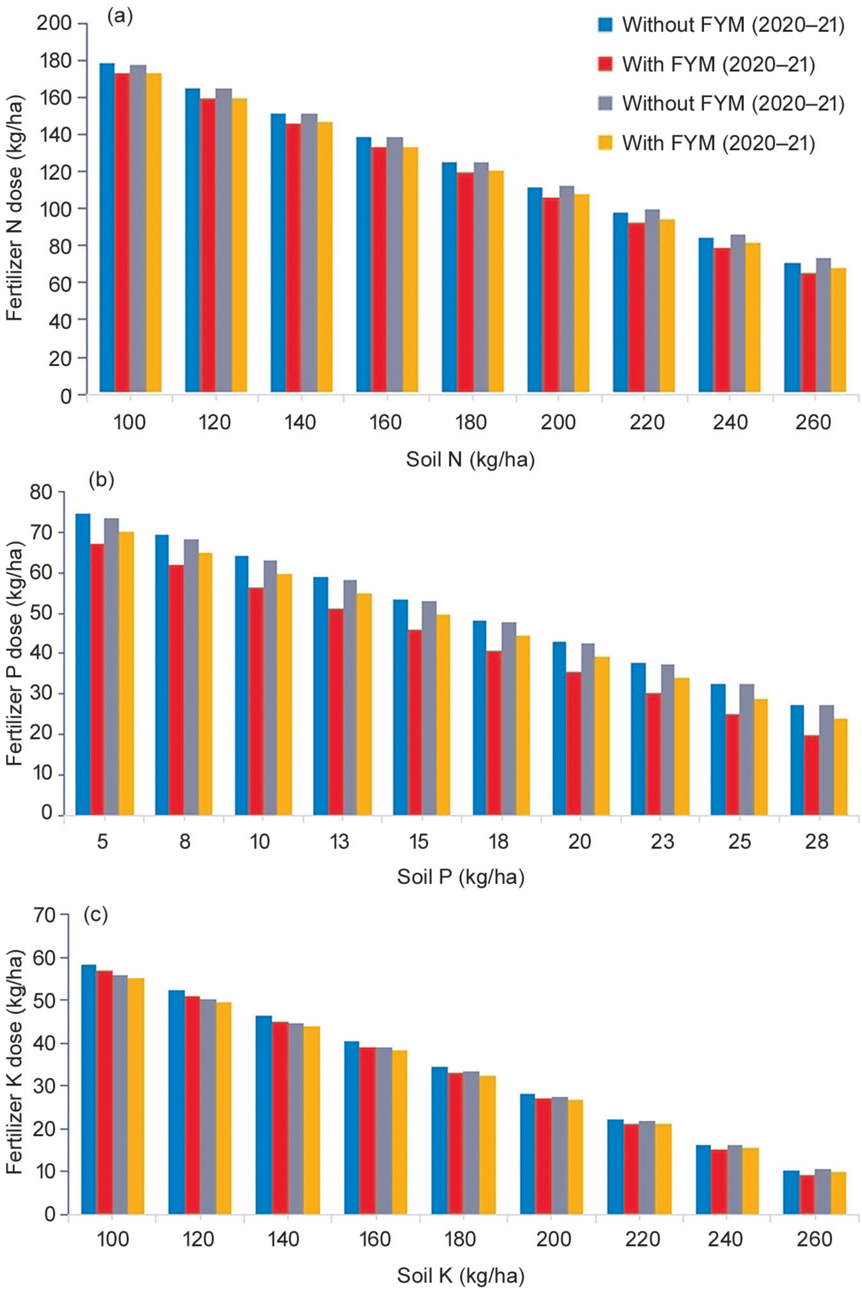

Fig 1 Soil test-based fertilizer prescription of nutrients (a) N, (b) P and (c) K for a targeted yield 55 q/ha of late-sown wheat grain yield with and without FYM (@10 t/ha) during 2021 and 2022.

investigation, inclusion of farmyard manure in integrated plant nutrition system could result in saving of fertilizer.

To get optimum production per unit of fertilizer and to balance out the input-output ratio for profit maximization, fertilizer prescription was developed for HD 3059. The prescription may be useful to achieve desired targeted yield of late-sown wheat under those soils having available N and K nutrient status between 100 and 260 kg/ha, while P status ranging between 5 to 28 kg/ha, specifically for soil conditions like NCR, Delhi. Based on soil test, fertilizer used by farmers in their fields may be profitable. Besides, it will be helpful in maintaining soil fertility and environmental sustainability

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