Indian Journal of Agricultural Sciences **91** (2): 244–8, February 2021/Article
https://doi.org/ 10.56093/ijas.v91i2.111599

Apposite macronutrient fertilization (AMNF) – an effective modus operandi for potato crop

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Received: 18 June 2020; Accepted: 20 October 2020

ABSTRACT

Potato is regarded as an important food crop, owing to its short duration, broader adaptability, nutritive supremacy and immediate returns. For getting more yields, farmers of Punjab are going for over fertilization of some nutrient and under fertilization of other which has resulted in inappropriate fertilization and consequently lower yields. Therefore, extension of adequate knowledge and awareness about these most important input components is utmost important for achieving optimum yield and better economic returns. So, the present investigation was initiated, during 2018–20 with the objective to reveal the extent of inappropriation of macronutrients followed in potato growing soils of Punjab. Information about average yield and fertilizer application rate was collected from 100 potato growing locations. Soils of all these locations were analyzed for various soil properties. It was observed that potato growers applied inappropriate amount of NPK. Application of more phosphorus (34.8–65.3 kg/ha) and less nitrogen (-68.4 to -85.8 kg/ha) and potassium (-38.3 to -66.8 kg/ha) has been practiced in these areas. The investigation further revealed that an increase in tuber yield (ranged between 2.04 to 4.51 t/ha) and consequently economic returns (₹15760–36020) can be achieved by following appropriate/recommended fertilization of macro nutrients.

Keywords: Economic returns, Macro-nutrients, NPK, Potato, Tuber yield

Potato farming, earlier focused on quantitative production, currently has diverse objectives. The reduced cost of production, better economic returns, appropriate fertilization along with environment protection (Yousaf *et al*. 2016) are among the focal objectives of modern potato farming. Besides feeding people, by being an important food source (Andre *et al*. 2014), potato serves as an important input component for industries also (Jagatee *et al*. 2015). Therefore, it has a wide range of utilization potential that makes its production even more important and attractive (Koch *et al*. 2020). Potato is the world's third most important food crop after rice and wheat (Pinhero *et al.* 2016). In India, potato is cultivated in an area of 2.15 million ha with a total production of 48.52 million tonnes having an average productivity of 22.56 t/ha (Anonymous 2018). Amongst the potato growing states, Punjab contributes around 2571.04 thousand tonnes from 98.52 thousand ha area (Anonymous 2019) and this region plays an important role in meeting the requirement of seed as well as table potato in India.

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Along with choice of cultivar, plant protection measures and irrigation, a further important agronomic measure for better and sustainable potato production is appropriate or balanced fertilization, especially of macro nutrients (Davenport *et al*. 2005). Imbalance and excessive use of chemical fertilizers without replenishment may leads to decline in soil health, and yield stagnation (Kumar *et al*. 2016, Sharma *et al*. 2017, Kumar *et al*. 2018 and Kongor *et al*. 2018). Although application of nutrients is necessary for augmenting crop yields (Yadav *et al*. 2000), but inappropriate or excessive nutrient addition does not guarantee constant increase in yields, and this may further result in low nutrient use efficiency, low economic returns and environmental problems (Guo *et al*. 2010, Tilman *et al*. 2011). As per the general opinion, the desire for higher yields has driven potato growers, especially of Punjab, towards inappropriate or over fertilization. Keeping in view the above-mentioned facts, the present investigation was carried out to reveal and quantify the extent of inappropriate fertilization, its impact on yield and economic returns, in major potato growing areas of Punjab.

MATERIALS AND METHODS

Selection of farmers: The present investigation was conducted during the year 2018–20, in three major potato producing districts of Punjab, i.e. Jalandhar, Hoshiarpur and Kapurthala (Anonymous 2015). A total of 100 potato farmers were selected from these three districts representing small, marginal, medium and large farmers. Harvested average potato tuber yield of the farmers were then used to group these 100 farmers into four different categories I - IV. Category I (C-I) included farmers with tuber yield (15–20 t/ha); category II (C-II) (>20–25 t/ha); category III (C-III) (>25–30 t/ha) and category IV (C-IV)(>30–35 t/ha). Most of the farmers (58%) were under category C–III, followed by category C-I (16%). The farmers in category C-II and C-IV were 15 and 11%, respectively. In total, around 80% of the farmers were getting, average tuber yield more than the country's average tuber yield (22.56 t/ha), whereas, 69% of the farmers were getting tuber yield more than the state average yield (26.09 t/ha).

Soil sampling and analysis: Surface soil samples (0–15 cm) collected from farmer's field were air dried, sieved (<2 mm) to remove coarse debris and stones. The processed soil samples were analysed for *p*H, organic carbon (Walkley and Black 1934), available N (Subbiah and Asija 1956), P (Olsen *et al*. 1954), K (Jackson 1973), Ca and Mg, DTPA extractable Zn, Fe, Cu, Mn by (Lindsay and Norvell 1978 and measured by atomic absorption spectrophotometry) following standard analytical procedure.

Determination of nutrient application, tuber yield and inappropriate fertilization: Survey based information regarding the nutrient application and average potato tuber yield was recorded through one to one interaction with selected farmers of these districts. The inappropriate fertilization of nutrient NPK was calculated on blanket nutrient recommendation basis 240:100:150 kg/ha (Kumar 2020).

Statistical analysis: Correlation studies were done through SPSS 16.0 software. Regression and trend analysis were done using MS-Excel programme.

RESULTS AND DISCUSSION

Physico-chemical properties of potato growing soils under diverse yield categories: Soil analysis revealed a very little variation in pH among different categories. Soil *p*H of sampled field in all categories ranged from 6.5–8.4 having mean value of 7.5. All the soils were having low average organic carbon content as well as available nitrogen. Average available phosphorus in all the categories was in high range except in category C-I (13.5 kg/ha). A very low variation in average available potassium, which was in medium range, was observed with values being: C-I (242.6 kg/ha); C-II (259.1 kg/ha); C-III (251.0 kg/ha) and C-IV (223.9 kg/ha). Secondary nutrients (Ca & Mg) and other micronutrients (Zn, Fe, Cu, and Mn) have also shown lesser variation in average contents. Average nitrogen application rate in these soils was 154.23 (C-I), 157.20 (CII), 161.67 (CIII) and 171.58 (C-IV) kg/ha, whereas the application rate of phosphorus in these soils was 134.84, 158.03, 165.31 and 167.69 kg/ha in category C-I, C-II, C-III and C-IV, respectively. The average potassium application rate was observed to be 83.25, 111.69, 96.40 and 103.64 kg/ha in C-I, C-II, C-III and C-IV, respectively.

Innate macro-nutrients content of potato growing soils under diverse yield categories: Considering the critical limit of avialable N:P:K in soil by Raina *et al*. (2007) (272-544:12-22:137-337 kg/ha) the available nitrogen content in soils was observed to be low in all categories of farmers with values ranging from 131.7–211 kg/ha. The low content of soil available N might be due low organic carbon content of these soils (Olowoboko *et al*. 2018) and inadequate replenishment of the lost or used nitrogen (Mafongoya *et al*. 2006) due to lower N application rate than the recommended. Moreover nitrogen losses (Jatav *et al.* 2013) due to leaching, volatilization, denitrification and surface run off can also be one of the reasons.

The avaiable phosphorus in soils of C-I farmers was medium (13.5 kg/ha), while in other categories it was in higher range (25.3–30.3 kg/ha). High available phosphorus in these soils might be due to high application rate of phosphatic fertilizers that has resulted in high build up of soil P (Sharma *et al*. 2008) as unlike nitrogen, P is not easily lost from the soil system. Hence appropriate application of P fertilizer should be followed in order to get optimum return from per unit application of phosphatic fertilizer. The potassium content was observed to be medium (223.9–259.1 kg/ha) in soils of all categories of farmers. Very little variation in available potassium content in all the soils was observed which can be attributed to its existance in dynamic equilibirum in soils (Sharma *et al*. 2010).

Inappropriate macronutrients application in soils under diverse yield categories: Data (Fig 1) indicating an inappropriate practice of NPK application (in comparison to recommended doses) followed by the farmers under all studied four categories. More phosphorus application and less nitrogen and potassium application rates were observed. Extent of these application rates was different in diverse yield category soils. The average overfertilization amount of phosphorus was 34.8, 58.4, 65.3, and 47.6 kg/ha in yield categories I, II, III and IV, respectively. A lesser amount of applied nitrogen than recommended dose was recorded in all the yield categories, viz. C-1 (-86.4 kg/ha); C-II (-82.1 kg/ha); C-III (-78.7 kg/ha) and C-IV (-68.4 kg/ha). Analysis of data further revealed that like nitrogen, potassium is also applied in lesser amounts than recommended, with values being -66.8, -38.3, and -53.6 and -46.4 kg/ha for C-I, C-II, C-III and C-IV categories, respectively. Zeal for getting more yield accompanied with unawareness about the nutrient requirement of the crop can be one of the many reasons for such an inappropriate fertilizer application rates in these soils. Plagiarism of application rates from neighboring potato growers has also been noticed as one of the possible reasons. Such an inappropriate fertilization not only effects yield but elevates cost of production as well as environmental deterioration.

Relationships between tuber yield and inappropriate application of macro nutrients: In order to understand the impact of inappropriate fertilization on potato yield a relationship between inappropriate fertilizer application rate

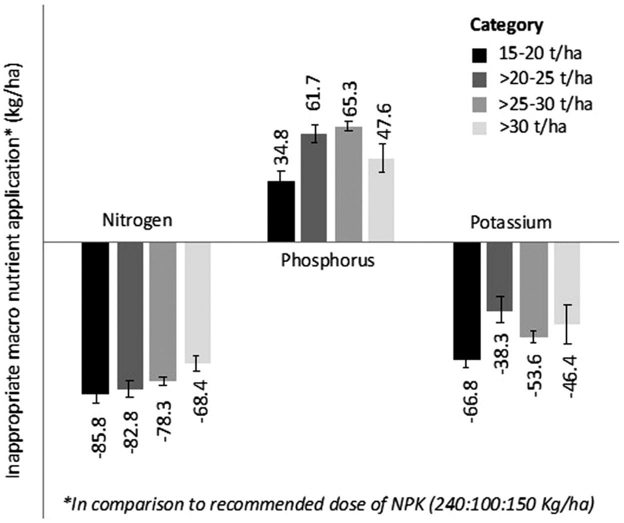

Fig 1 Extent of inappropriate macro nutrient fertilization in soils with diverse harvested yield categories in major potato growing areas of Punjab.

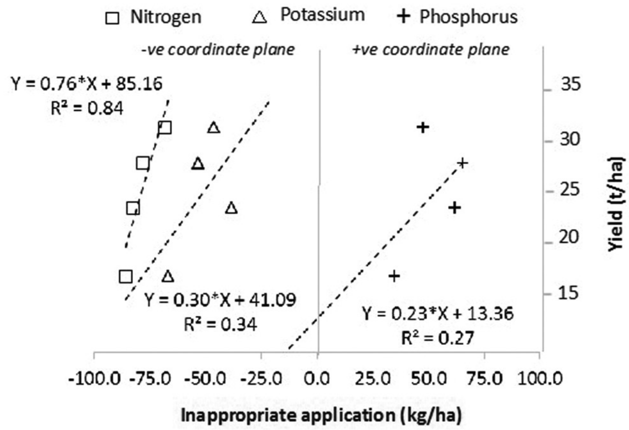

Fig 2 Relationship between tuber yield and inappropriate fertilization of NPK in major potato growing areas of Punjab.

and yield was studied. Farmers of all the four yield categories were following inappropriate fertilization (Fig 2). Trend lines in negative and positive coordinate plane represent less and excess application rates. A positive and linear relationship between yield and reducing inappropriation of N as well as K application was observed which can be understood by equations 1 and 2.

Yield (t/ha) = 0.76*Inappropriation of N (kg/ha) + 85.16 (1)

Yield (t/ha) = 0.30*Inappropriation of K (kg/ha) + 41.09 (2)

These regression analysis further revealed that inappropriation of nitrogen accounted for 84% variation whereas inappropriation of K accounted for only 34% variation in tuber yield in these soils. It was further observed that phosphorus inappropriation (increasing) was also having linear and positive relationship with yield but it accounted for only 27% variation to yield. This relationship can be understood using the equation 3.

Yield (t/ha) = 0.23*Inappropriation of P (kg/ha) + 13.36 (3)

These equations suggest that nitrogen seems to be the only yield limiting nutrient in all the yield categories (Fig 2). Hence, indicated that increasing the application of nitrogen would positively affect the yield. These results are similar to the results obtained by Bucher and Kossmann (2011) and Silva *et al*. (2013), according to whom N has the greatest impact on potato yield formation among all essential macronutrients as it ensures optimal photosynthate production in leaves and consequently optimal tuber growth and yield (Mazumdar *et al*. 2020).

Correlation and regression studies to understand relationship among tuber yield and applied macro nutrients: It was observed that tuber yield showed a positive and highly significant correlation with applied nitrogen in the entire yield category soils, i.e. C-I (r=0.741**), C-II (r=0.687**), C-III (r=0.648**) and C-IV (r=0.754**). Applied potassium had a significant and positive correlation with tuber yield only in C-I (r=0.503*) category soils. The tuber yield of potato in all the categories had not shown any significant correlation with applied phosphorus. These correlation studies again reflect the importance of applied nitrogen in optimizing tuber yield in these soils.

Further in order to reflect the influence of applied macro nutrients on tuber yield, multiple regression models were developed. It was observed that applied NPK accounted for 60, 55, 42 and 72% variation in tuber yield in C-I, C-II, C-III and C-IV yield categories. It was further observed that only applied nitrogen had a significant influence on tuber yield in all the category soils. These regression models (eq. 4 to 7), can further be used for yield prediction in potato growing areas of Punjab.

Yield (C-I) = 13.45 + 0.019 X *Ap* N* + 0.003 X *Ap* P + 0.009 X *Ap* K, R^2= 0.60* (4)

Yield (C-II) = 11.85 + 0.051 X *Ap* N * + 0.020 X *Ap* P + 0.001 X *Ap* K, R^2= 0.55* (5)

Yield (C-III) = 20.50 + 0.05 X *Ap* N ** + 0.001 X *Ap* P – 0.009 X *Ap* K, R^2= 0.42** (6)

Yield (C-IV) = 27.84 + 0.044 X *Ap* N - 0.021 X *Ap* P + 0.002 X *Ap* K, R^2= 0.72* (7)

(Where *, ** denotes significance at p<0.05 and 0.01, respectively. Ap: Applied)

Economic returns after nullifying inappropriation of macro nutrient application: In the present investigation, inappropriate fertilizers application had remarkably affected the economic returns. Recommended application of nutrients in the form of fertilizer had saved extra cost incurred in C-II (₹ 677.79/ha) & C-III (₹ 424.54/ha), whereas in C-I and C-IV the cost per hectare due to fertilizer appropriation has increased by ₹ 1520 and ₹ 60.23/ha in former and later categories (Table 1). Regression models developed in the present investigation were used to anticipate yield as influenced by appropriate macro nutrient application. The results of these models revealed a yield increase of

Table 1 Applied NPK based economic balance in soils belonging to diverse yield categories in major potato growing areas of Punjab

Category (Yield group) (t/ha)	NPK needed to be added/reduced to nullify inappropriation* (kg/ha)			Fertilizer needed to be added/ reduced for nullifying inappropriation (kg/ha)			Cost of fertilizers, to be added/reduced for nullifying inappropriation (₹)**			Aggregate fertilizer based economic balance per ha (₹)***
	N	P	K	Urea	DAP	MOP	Urea	DAP	MOP	
15-20	85.8 (±5.3)	-34.8 (±6.2)	66.8 (±4.2)	216.09 (±12.20)	-75.73 (±13.45)	11.25 (±6.95)	1246.90 (±70.42)	1817.60 (±322.74)	2091.50 (±130.71)	1520.80
>20-25	82.8 (±4.8)	-61.7 (±5.0)	38.3 (±7.4)	232.50 (±13.15)	-134.16 (±8.91)	63.86 (±12.34)	1341.50 (±75.89)	3219.80 (±213.73)	1200.51 (±231.92)	-677.79
>25-30	78.3 (±2.3)	-65.3 (±2.7)	53.6 (±3.6)	225.84 (±5.28)	-141.99 (±5.90)	89.33 (±5.96)	1303.10 (±30.44)	3407.70 (±141.64)	1679.36 (±112.02)	-424.54
>30-35	68.4 (±3.8)	-47.6 (±7.8)	46.4 (±11.0)	189.24 (±13.03)	-103.52 (±16.93)	77.27 (±18.32)	1091.90 (±75.17)	2484.40 (±406.37)	1452.73 (±344.45)	60.23

*As per recommended dose; **Rates of Urea, DAP and MOP per quintal are ₹577.00, 2400.00 and 1880.00, respectively, ***Cost of DAP subtracted from combined cost of Urea and MOP

Table 2 Observed and anticipated yield based economic returns after nullification of inappropriate NPK fertilization in soils belonging to diverse yield categories in major potato growing areas of Punjab

Category (Yield group) (t/ha)	Average yield obtained (t/ha)	Anticipated yield after nullifying inappropriation (t/ha)*	Anticipated yield elevation (t/ha)	Additional income from yield increase (₹)**	Total additional income per hectare (inclusive economic balance)(₹)***
15-20	17.50	19.66	2.16	17280	15760
>20-25	24.20	26.24	2.04	16320	16998
>25-30	28.60	31.26	2.66	21280	21705
>30-35	32.10	36.61	4.51	36080	36020

*Using empirical models developed during the present study; ** @ ₹ 8000.00/t; ***Impact of only NPK appropriation and consequent tuber yield enhancement is considered (reduced cost of fertilizers applied is added, and additional cost is subtracted)

2.16, 2.04, 2.66 and 4.51 t/ha in category C-I, C-II, C-III and C-IV, respectively. So, for final returns, when we calculate returns considering yield elevation also (Table 2), a noticeable increase in economic returns in the form of perks in all the categories of farmers was observed. An economic boost of ₹ 15760, 16998, 21705 and 360201/ha in yield categories C-I, C-II, C-III and C-IV, respectively can be realized merely by following appropriate or recommended fertilization. A significant increase in tuber yield by an average 2.98 t/ha and farmers income by nearly 200 US $/ha due to more balanced/appropriate "recommended" fertilization has been observed in potato growing soils of China (IPNI Canada 2012).

There is a huge inappropriate application of macronutrients NPK in major potato growing areas of Punjab. Most of the farmers are applying high amount of phosphorus in the form of costlier fertilizer diammonium phosphate. Hence, potato farmers in these areas require most urgent attention addressing appropriate/recommended soil nutrient application. Potato tuber yield and consequently the economic returns in these areas can be improved by appropriate macro nutrient fertilization. The findings of the paper can be used by planners and policy makers to frame and implement effective strategies for promoting appropriate macro nutrient fertilization among the potato growers of the region. Further the empirical models developed can be used for tuber yield predictions on the basis of applied macro-nutrients but after proper validation.

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