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Pooja Pandey
Department of Vegetable Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Manoj Raghav
Department of Vegetable Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Kailash Sati
Department of Vegetable Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Jyoti Bajeli
Department of Horticulture, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Arunima Tripathi
Department of Horticulture, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Correspondence
Jyoti Bajeli
Department of Horticulture, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Impact of nitrogen schedule on leaf indicate, yield and tuber quality of potato

Pooja Pandey, Manoj Raghav, Kailash Sati, Jyoti Bajeli and Arunima Tripathi

Abstract
A two year study was carried out in order to explore the response of nitrogen scheduling on leaf indicate, yield and tuber quality of potato (cv. Kufri Sadabahar). The experiment was conducted in a complete randomized block design with three replications at Vegetable Research Centre of GBPUAT, Pantnagar, Uttarakhand, India in *Rabi* season of 2014-15 and 2015-16. During the study, leaf indicates like leaf area index (LAI), harvest index, leaf chlorophyll content, yield attributes and tuber quality indices were recorded. On the basis of pooled data, treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) gave maximum leaf area index (5.0). Maximum chlorophyll 'a' (0.79 mg/g) and 'b' (0.86 mg/g) content was recorded with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP), whereas, highest number of tuber and highest tuber yield per hectare was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). With respect to quality, it was observed that protein content in tuber was increased with increasing nitrogen dose. Highest dry matter content and specific gravity was recorded with treatment T_7. However, a maximum total soluble solid in tuber was recorded with treatment T_1.

Keywords: Chlorophyll content, leaf area index, tuber yield, dry matter, protein content

1. Introduction

Potato is a major non cereal and staple food crop in the world next to rice, wheat and maize. It is an important crop for the high population areas of Asia because it produces more dry matter content, well-balanced protein and more calories per unit area of land and time than any other major food crops. The problem of malnutrition can be largely solved if potato is accepted as a major food and not merely as a vegetable. Potato is a short duration, high yielding but nutrient exhaustive crop. So, use of balanced fertilizers with best management practices is necessary and pre-requisite for getting better and higher yield of this crop. Nitrogen is one of the foremost management priorities in potato cropping systems (Stark *et al*. 2004) [18]. The studies of Chare *et al.* 1990 [6] also indicate that nitrogen is the major nutrient in potato production and much variability exists in nitrogen requirements between cultivars. It determines the quantity and structure of potato yield, its chemical composition and tuber quality (Kolodziejczyk, 2014) [12]. Nitrogen fertilizer is a key nutrient in the production of non-legume crops. Besides that, it is a major component in many biological compounds that plays a vital role in photosynthetic activity and crop yield capacity. Nitrogen is part of the enzymes associated with chlorophyll synthesis and the chlorophyll concentration reflects the relative crop nitrogen status as well as yield level. Use of nitrogenous fertilizer in right amount, at right time and by right method can enhance crop growth, yield as well as quality of the tuber. The aim of this research was to realize the effect of nitrogen fertilizer scheduling on leaf indicate, tuber yield and tuber quality of potato in *tarai* region of Uttarakhand.

2. Materials and Methods

2.1 Experimental Site

The experiment was undertaken during *Rabi* season of the year 2014-15 and 2015-16 at Vegetable Research Centre (VRC) of the G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (Uttarakhand). Geographically, Pantnagar is located at the foot hills of Himalayas at 29° North latitude and 79.3° East latitude. The altitude of this place is 244.0 m above mean sea level.

The *Tarai* region is characterized by humid subtropical climate with maximum temperature ranging from 30 ˚C to 43 ˚C in summer and minimum ranging from 4.5 ˚C to 26.7 ˚C in winter. The summers are hot and dry, winters are cold and rains are heavy (average rainfall 1400 mm). Monsoon occurs from the third week of June to the end of September. July and August are the wettest months (mean 350-425 mm rainfall). The mean relative humidity remains almost 80-90% at 7:00 a.m. from mid of June to end of February and then it steadily decreases to 50% by the first week of May and remain still mid-June. Frost can be expected from the last week of December to middle of February. Occasionally light rains are expected during winter.

2.2 Experimental design and detail of treatments

The experiment was laid out in Randomized Block Design that was consisted of ten treatments replicated thrice and each treatment was allocated randomly in each block. Recommended dose of N: P_2O_5:K_2O was 160:100; 120 kg/ha. Whole dose of P_2O_5 and K_2O was applied at the time of planting whereas; nitrogen was applied according to the treatment (Table 1). The numerical data of all the components were subjected to analysis of variance (ANOVA) using randomized block design to calculate critical difference (CD). Statistical analysis of data was done following standard procedures (Snedecor and Cochran, 1967).

Table 1: Detail of treatments

	Factor levels
T_1	50% N of RDF as basal + 50% top dressing at 25 DAP
T_2	50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP
T_3	25% N of RDF as basal + three foliar spray of urea @ 2% at 25, 40 & 55 DAP
T_4	50% N of RDF as basal + two foliar spray of urea @ 2% at 25 & 40 DAP
T_5	50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP
T_6	50% N of RDF as basal + three foliar spray of urea @ 3% at 25, 40 & 55 DAP
T_7	50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP
T_8	25% N of RDF as basal + 75% top dressing at 25 DAP
T_9	25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP
T_{10}	Control (No application of nitrogen)

2.3 Observations recorded

The observations regarding leaf indicate, tuber yield and quality were recorded, accordingly. Leaf Area Index was taken with the help of leaf area meter from five randomly selected plants before de-haulming and calculated by following formula:

$$\text{Leaf area index} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Leaf area(area covered in cm}^2\text{ per plant)}}$$

Chlorophyll content (“a” and “b”) in leaf was estimated before de-haulming by taking leaves from five randomly selected plants from each plot and calculated through the method given by Bruinsma (1963).

The harvest index per plot from different treatments was calculated with the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Where,

Economic yield = Total tuber yield

Biological yield = Total tuber yield + Total haulm yield

The total number of tubers and total yield per hectare (t ha^{-1}) was calculated on the basis of number of tubers and yield per plot and converted into tonnes per hectare. Dry matter content of tuber was determined by oven drying method in which, 100 g fresh tuber weight from each treatment was taken and dried in oven at 80 ºC till constant. Subsequently the dry weight of tuber was recorded in per cent and calculated by using following formula -

$$\text{Dry matter content (\%)} = \frac{\text{Oven dried weight of tuber (g)}}{\text{Fresh weight of tuber (g)}} \times 100$$

Protein content was determined through the procedure given by Ranganna (1986) [16]. After determination of the nitrogen content in tuber (%), the protein content was calculated by following conversion formula given by AOAC (2000):

$$\text{Protein (\%)} = \text{Nitrogen (\%)} \times 6.25$$

For Total Soluble Solids (T.S.S.) estimation, potato tuber juice was extracted from each representative sample and used by hand held digital refractrometer at room temperature. The results were expressed in terms of per-cent. Tuber specific gravity was estimated by taking a representative sample of tubers from each plot after harvesting and weighed, simultaneously. The volume of same tubers was determined by water displacement method. The specific gravity was determined by following formula:

$$\text{Specific gravity of tuber (g/cm}^3\text{)} = \frac{\text{Weight of tuber (g)}}{\text{Volume of water displaced (cm}^3\text{)}}$$

3. Results and discussion

3.1 Leaf Area Index (%)

The mean values for the effects of different nitrogen schedules on evaluated traits *viz*., leaf, yield and quality of potato are presented in Table 2. The effects of nitrogen levels were significant for all the characters. LAI is the ratio of leaf surface to the area covered by the plant canopy. Pooled data over the years showed maximum LAI (5.0) with treatment T_9 and T_1 which was at par to treatment T_8 (4.9) and T_4 (4.7). The minimum LAI (2.5) was recorded with treatment T_{10}. The LAI was increased with adequate nitrogen application during vegetative stage. Moreover, an additional foliar spray further enhanced it. It might be due to the rapid leaf expansion caused by adequate nitrogen supply resulted in high LAI. However, excess nitrogen supply reduced carbohydrate accumulation which reduced leaf expansion. Consequently, lesser leaf area index was registered in treatment T_5. On the other hand, untreated plants showed less LAI as compared to treated one. Similar to these findings Martin *et al*. (2001) [14] recorded a quick decline in leaf area index in case of absence of nitrogen. Moreover, Agu (2004) [1] reported that leaf area index increased when nitrogen was applied at the time of sowing and decreased with delay in the application.

3.2 Chlorophyll Content (mg/g)

Maximum chlorophyll ‘a' content (0.79 mg/g) was recorded with treatment T_8 which was found superior to all other treatments. Similarly, chlorophyll ‘b' content was also recorded maximum with treatment T_8 and was at par to treatments T_7 and T_9 (0.83 mg g^{-1}). Minimum chlorophyll ‘a' content (0.61 mg g^{-1}) and chlorophyll ‘b' content (0.75 mg g^{-1}) was recorded with treatment T_{10}. The results revealed that chlorophyll content was increased with increase in nitrogen application. It might be due to the nitrogen which is a structural element of chlorophyll and protein molecules, and thereby affects formation of chloroplasts and accumulation of chlorophyll in leaves (Tucker, 2004) [20]. Ciecko *et al.* (2012) [8] reported a linear increase in the content of Chl ‘a' and Chl ‘b' in potato leaves by increasing share of nitrogen.

3.3 Harvest Index (%)

It is evident from the data (Table 2) that nitrogen scheduling significantly affected harvest index. Maximum harvest index was recorded with T_9 (71.2%) which was at par to T_8 (69.4 %) whereas, it was recorded minimum with T_{10} (60.4%). Critical observation of the data (Table 2) revealed that adequate amount of nitrogen application either through topdressing or topdressing + foliar spray at tuberization stage gave more harvest index due to the synchrony between demand and supply of nitrogen rather than basal or later application. Similar to these findings Sun *et al.* (2012) [19] recorded maximum harvest index in potato with application of nitrogen at planting in conjunction with dressing at 20 days after emergence. Kumar (2015) [13] also recorded maximum harvest index when nitrogen applied as basal + topdressing + foliar spray.

3.4 Total Number of Tubers

Highest number of tubers was counted with treatment T_9 (720 thousand tubers ha^{-1}) which was at par to treatment T_8 (672 thousand tubers ha^{-1}). Minimum were counted with treatment T_{10} (430 thousand tubers ha^{-1}). The results revealed that split application (basal + topdressing + foliar) of nitrogen gave better response than that of recommended. Nitrogen may increase the sink strength by increasing number of tubers. More number of tubers was might be due to more number of haulms and more nitrogen uptake as recorded with treatment T_9. Similar results were obtained by Sahu *et al.* (2014) [17]. The number of tubers is increased with increase in number of stolons, number of haulms and nitrogen uptake as reported by Zabihi-e-Mahmoodabad *et al.* (2010) [21].

3.5 Total yield per hectare (t/ha)

Maximum tuber yield was recorded with treatment T_9 (34.08 t ha^{-1}) which was statistically similar with treatment T_8 (32.33 t ha^{-1}). Minimum tuber yield per hectare was recorded with treatment T_{10} (18.90 t ha^{-1}). The data (Table 2) indicated that maximum tuber yield was recorded when adequate amount of nitrogen was applied in split form (basal + topdressing + foliar) and it could not be replaced by consecutive foliar spray. The period from tuber initiation to mid-tuber bulking is critical for potato plants because of vegetative and storage growth advance together. Plants having more plant height, number of leaves, LAI produced more tuber yield because of more photosynthates formation and their translocation and accumulation to the tuber. It was also due to more LAI, plant vigour, number and weight of tubers per plant as also reported by Badr *et al.* (2012) [2], Diengdoh *et al.* (2012) [9] and Getie *et al*. (2015) [10].

3.6 Dry Matter Content (%)

With respect to quality parameters, maximum dry matter content in tuber was recorded with treatment T_7 (19.3%) which was at par to treatment T_3 (18.6%). It was recorded minimum with treatment T_5 (16.2%). Dry matter content was increased with decrease in nitrogen dose (basal + foliar). It might be due to the lower concentration of nitrogen in foliar directly absorbed by leaf which promotes photosynthesis, and consequently results in more dry matter formation. On the other hand, intensive application of nitrogen reduced dry matter content due to interference in carbohydrate assimilation in tuber as in case of T_5 and T_8. Application of optimum dose of nitrogen at appropriate time increased translocation of more photosynthates from source to sink has occurred up to maturity as a result of increased nutrient absorption by plant. Similarly Chen and Setter (2012) [7] reported that strong leaf and stem sink capacity before tuber initiation compete with developing tubers for photosynthates which reduce dry matter accumulation in tuber.

3.7 Protein Content (%)

Maximum protein content (7.7%) was recorded with treatment T_5 which was at par to all other treatments except T_3, T_4, T_7 and T_{10}, respectively. The minimum protein content (6.5%) was recorded with treatment T_{10}. From the results, it could be assessed that protein content was increased with increase in nitrogen application. Excess amount of nitrogen leads to increase nitrogen content in tuber consequently more protein formation takes place. The significant effect on protein content could be related to the vital role of nitrogen in the plant that associated directly or indirectly with protein synthesis in tuber as reported by Chandra *et al.* (2014) [4].

3.8 Total Soluble Solids (T.S.S. %)

The maximum T.S.S. (6.3%) was registered in treatment T_1 which was statistically similar with treatment T_2 (6.2%) while, it was recorded minimum in treatment T_{10} (4.1%). The results (Table 2) indicate that higher total soluble solids in tuber was due to the application of nitrogen as basal + topdressing and basal + topdressing + spray. It was also increased with high basal dose of nitrogen. Later application of high nitrogen dose reduces T.S.S. content of the tuber. The probable reason of this reduction might be due to consistent increase in water content and turgidity of cells in tubers with increase in nitrogen at later stage (Banu *et al.* 2007) [3]. The study conducted by Jatav *et al.* (2017) [11] recorded an increase in T.S.S. content with nitrogen application upto150 kg ha^{-1} and further increase in nitrogen decreased it.

3.9 Specific gravity of tuber (g/cm^3)

Specific gravity was recorded maximum (1.09 g/cm^3) with treatment T_7 which was at par to all other treatments except T_5 whereas minimum specific gravity (1.05 g/cm^3) was recorded with treatment T_5. Specific gravity is an important quality attribute of potato for chips making and French fries because it affects the thickness, colour, crispness, oiliness, taste and recovery rate of the product. Maximum specific gravity was recorded with basal + topdressing + foliar application of nitrogen. From the results, it is cleared that in contrast to protein content specific gravity of potato is reduced by application of more nitrogen. It might be due to the increase in dry matter content of tuber with decreasing nitrogen dose which enhanced the carbohydrate accumulation in tuber and decreased protein formation resulted in more specific gravity. The findings are in agreement with the findings of Ozturk *et al.* (2010) [15] and Chandra *et al.* (2017) [5].

4. Conclusion
As a result of two years research on potato, it can be concluded that nitrogen scheduling with topdressing and foliar application enhances leaf indicates as well as yield of the tubers. Moreover, the protein content was directly correlated with nitrogen application. However, to increase the dry matter content and specific gravity, more nitrogen as basal and small quantity at later stages through foliar application is required.

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