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Effect of Nitrogen Management on Tuber Size Distribution and Seed Potato Production

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ABSTRACT

A field experiment was conducted during the rabi seasons of 2022–23 and 2023–24 at the ICAR–Central Potato Research Institute, Regional Station, Patna, Bihar, to evaluate different nitrogen (N) application schedules influence on tuber number, tuber size distribution, seed tuber yield, dry matter production, multiplication rate and economic returns in potato. Nine N management schedules were evaluated in a randomized complete block design using cv. Kufri Jyoti. The treatments differed in the proportion of the recommended N dose applied at planting and earthing up and, in selected treatments, supplemental foliar N sprays at 25, 40 and/or 55 days after planting (DAP). The recommended N dose for seed crop (150 kg N ha^{-1}), applied as 50% at planting and 50% at earthing up, produced the highest total tuber number (645 × 10^3 ha^{-1}), total tuber yield (25.5 t ha^{-1}), multiplication rate by number (7.74), multiplication rate by weight (7.3), fresh haulm yield (15.9 t ha^{-1}), dry tuber yield (4.76 t ha^{-1}) and dry biological yield (7.92 t ha^{-1}). The same treatment also generated the highest gross return (510.6 × 10^3 ha^{-1}), net return (314.9 × 10^3 ha^{-1}) as well as benefit: cost ratio (2.61). The results indicate that, under the experimental conditions, supplying the full recommended N dose through soil application in two splits was more effective for overall seed tuber production than reducing soil-applied N and compensating through foliar sprays. The response was expressed not only as greater total yield but also as a higher number and yield of the commercially important 50–75 g and >75 g seed tuber grades.

Keywords: Nitrogen management, Seed potato, Tuber size distribution, Tuber yield, Multiplication rate, Economic return

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INTRODUCTION

Potato (*Solanum tuberosum* L.) is a high-yielding crop in which both total tuber production and the distribution of tubers among size classes determine the value of seed produced. For seed potato, the objective is not simply to maximize total tuber biomass; production of an adequate proportion of desirable seed grades is equally important because tuber size influences handling, planting value and multiplication efficiency (Hirpa et al., 2010). Thus, fertilizer practices that alter canopy development, tuber initiation and subsequent bulking can change the number and size distribution of harvested seed tubers. Nitrogen (N) is a major nutrient governing potato growth and productivity. Insufficient N restricts vegetative growth and can reduce tuber number and yield, whereas excessive or poorly timed N may prolong vegetative growth and alter tuber set and bulking (Kleinkopf et al., 1981; Westermann and Kleinkopf, 1985). The response to N is also influenced by cultivar, soil fertility, moisture supply and season (Kleinkopf et al., 1981; Zelalem et al., 2009). Consequently, the agronomic value of an N treatment cannot be judged from total yield alone when the crop is grown for seed.

Previous studies have established that N application affects potato yield and dry-matter production. Increased N availability may enhance leaf and stem growth and increase the assimilate supply available for tuber development, while N limitation can reduce tuber number and total tuber weight (Kleinkopf et al., 1981; Judith et al., 2019). Studies on nutrient management in potato have also shown that N is often a major yield-limiting nutrient and that balanced fertilization can improve the production of marketable and larger tubers (Sharma and Arora, 1987; Zelalem et al., 2009). However, the optimum N schedule for producing an appropriate seed tuber size profile under the agro-ecological conditions of the eastern Indo-Gangetic Plain is less clearly defined.

Foliar N application has the potential to supplement soil-applied N during crop growth, but its effectiveness depends on the amount and timing of N supplied through the soil and foliage (John et al.,2009). From a seed-production perspective, comparing split soil application of the recommended N dose with reduced soil N supplemented by foliar sprays is therefore relevant for identifying a practical N schedule that simultaneously supports total tuber yield and desirable seed size grades.

The present study was undertaken to evaluate nine N application schedules in potato under the conditions of ICAR–CPRI Regional Station, Patna, with particular emphasis on (i) growth attributes, (ii) number and yield of different

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tuber size grades, (iii) total seed tuber yield and multiplication rate, (iv) dry matter production and harvest index, and (v) economic returns. The specific hypothesis was that N rate and timing would modify tuber size distribution and that an appropriate split N schedule would improve the production of desirable seed tuber grades.

MATERIALS AND METHODS

Experimental site and crop

The experiment was conducted during the rabi seasons of 2022–23 and 2023–24 at the experimental farm of ICAR–Central Potato Research Institute, Regional Station, Patna, Bihar, India (25°35′46″N, 85°04′32″E; 75 m above mean sea level). The experimental soil was clay loam, with 0.42% organic carbon, electrical conductivity of 0.11 mS m^{-1}, pH 6.8 and bulk density of 1.46 g cm^{-3}. The initial available N, P and K contents were 238.2, 23.4 and 262.4 kg ha^{-1}, respectively. Potato cv. Kufri Jyoti was used in both seasons.

Experimental design and nitrogen treatments

The experiment was laid out in a randomized complete block design (RCBD). Nine nitrogen management schedules were evaluated. The recommended dose of N (RDF-N) was 150 kg N ha^{-1}. The treatment schedule was: F1, 50% RDF-N at planting + 50% RDF-N at earthing up; F2, 50% RDF-N at planting + 25% RDF-N at earthing up; F3, 25% RDF-N at planting + 25% RDF-N at earthing up; F4, 50% RDF-N at planting + 25% RDF-N at earthing up + one foliar N spray at 40 DAP; F5, 25% RDF-N at planting + 25% RDF-N at earthing up + one foliar N spray at 40 DAP; F6, 50% RDF-N at planting + 25% RDF-N at earthing up + foliar N sprays at 40 and 55 DAP; F7, 25% RDF-N at planting + 25% RDF-N at earthing up + foliar N sprays at 40 and 55 DAP; F8, 50% RDF-N at planting + foliar N sprays at 25, 40 and 55 DAP; and F9, 25% RDF-N at planting + foliar N sprays at 25, 40 and 55 DAP.

Crop establishment and management

Phosphorus (60 kg P_2O_5 ha^{-1}) and potassium (100 kg K_2O ha^{-1}) were applied at planting. The crop was planted on 1 November 2022 and 3 November 2023 at 60 × 20 cm spacing using 40–50 g seed tubers at a seed rate of 3.5 t ha^{-1}. Basal fertilizer was placed approximately 5 cm below the planting position and covered with soil before planting. The remaining N was applied according to the treatment schedule. Recommended cultural and seed-plot practices were followed uniformly in both seasons. Haulm killing was carried out on 22 January 2023 and 25 January 2024, and the crop was harvested manually on 10 February 2023 and 15 February 2024, respectively.

Observations and calculations

Plant emergence, plant height, number of stems per plant, compound leaves per plant and fresh haulm yield were recorded as growth attributes. Plant height and number of stems per plant were assessed at peak crop growth. At harvest, tubers were graded into <25, 25–50, 50–75 and >75 g classes, and the number and weight of tubers in each grade were recorded. Total tuber number and total tuber yield were obtained by summing the four grades. Dry tuber and haulm yields were determined after drying plant samples at 65°C to constant weight. Dry biological yield was calculated from dry tuber plus dry haulm yield. Harvest index was calculated as dry tuber yield divided by dry biological yield × 100. Multiplication rate by number was calculated as total harvested tuber number divided by planted seed-tuber number, while multiplication rate by weight was calculated as harvested tuber weight divided by planted seed-tuber weight. Cost of cultivation, gross return, net return and benefit: cost ratio was calculated from the treatment-wise production costs and returns recorded for the experiment.

Statistical analysis

Data were analyzed using the OPSTAT statistical package (CCS Haryana Agricultural University, Hisar). Treatment means were compared using the standard analysis of variance procedure for the experimental design, and the critical difference (CD) at the 5% probability level was used for mean separation where the treatment effect was significant. The results are presented as two-year mean values.

RESULTS AND DISCUSSION

Growth attributes

Nitrogen management affected fresh haulm production and plant height, whereas plant emergence, stem number and compound-leaf number did not show significant treatment differences. Plant emergence ranged from 80.9 to 91.1%, with the highest value under 50% RDF-N at planting + 50% RDF-N at earthing up (91.1%). Plant height was also highest under 50% RDF-N at planting + 50% RDF-N at earthing up (38.8 cm), followed by 50% RDF-N at planting + foliar N sprays at 25, 40 and 55 DAP (35.7 cm), although the treatment effect on plant height was not significant. The number of stems per plant varied from 3.3 to 4.0 and compound leaves per plant from 28.3 to 37.3. Fresh haulm yield, in contrast, responded significantly to N management and was highest under 50% RDF-N at planting + 50% RDF-N at earthing up (15.9 t ha^{-1}), exceeding the other treatments. The stronger response of haulm production than of emergence or stem number suggests that N availability primarily influenced vegetative biomass rather than establishment under the conditions of the experiment.

Tuber number and size distribution

Nitrogen management significantly modified the number of tubers in the <25 and 25–50 g classes and the total number of tubers. 50% RDF-N at planting + 50% RDF-N at earthing up produced the highest number of <25 g tubers (275 × 10^3 ha^{-1}), whereas 50% RDF-N at planting + 25% RDF-N at earthing up + one foliar N spray at 40 DAP produced the highest number of 25–50 g tubers (188 × 10^3 ha^{-1}), closely followed by 50% RDF-N at planting + 50% RDF-N at earthing up (187 × 10^3 ha^{-1}). For the 50–75 g and >75 g classes, treatment differences were not significant, although the numerical maxima occurred under 50% RDF-N at planting + 25% RDF-N at earthing up + foliar n sprays at 40 and 55 DAP (119 × 10^3 ha^{-1}) and 50% RDF-N at planting + 50% RDF-N at earthing up (78 × 10^3 ha^{-1}), respectively. The highest total tuber number was recorded under 50% RDF-N at planting + 50% RDF-N at earthing up

(645 × 10^3 ha^{-1}), statistically comparable with 50% RDF-N at planting + 25% RDF-N at earthing up + foliar N sprays at 40 and 55 DAP (579 × 10^3 ha^{-1}) but significantly higher than the remaining treatments. The greater total tuber number under full recommended N may reflect improved crop growth and assimilate availability during tuber initiation and early bulking. This interpretation is consistent with earlier observations that N limitation can reduce tuber number in potato (Kleinkopf et al., 1981; Judith et al., 2019, Geofrey et al., 2014).

Tuber yield

Total tuber yield responded significantly to N management (Shahazad et al., 2010). Application of 50% RDF-N at planting + 50% RDF-N at earthing up produced the highest total yield (25.5 t ha^{-1}), followed by 50% RDF-N at planting + 25% RDF-N at earthing up + one foliar N spray at 40 DAP (21.8 t ha^{-1}) and 50% RDF-N at planting + 25% RDF-N at earthing up + foliar N sprays at 40 and 55 DAP (21.3 t ha^{-1}). The yield advantage under 50% RDF-N at planting + 50% RDF-N at earthing up was associated particularly with greater production of the 50–75 g (8.8 t ha^{-1}) and >75 g (8.3 t ha^{-1}) grades. For the 25–50 g grade, 50% RDF-N at planting + 25% RDF-N at earthing up + one foliar N spray at 40 DAP produced the highest yield (6.1 t ha^{-1}), but the total yield remained lower than under 50% RDF-N at planting + 50% RDF-N at earthing up. The <25 g grade was not significantly affected by N management. These results indicate that supplying the complete recommended N dose through two soil applications was more effective for overall seed tuber production than replacing part of the soil-applied N with foliar sprays. Adequate N availability during canopy development and tuber bulking can increase assimilate supply and support tuber growth, whereas inadequate N may restrict both tuber number and tuber weight (Westermann and Kleinkopf, 1985; Zelalem et al., 2009; Jatav et al., 2017).

Dry matter production and harvest index

50% RDF-N at planting + 50% RDF-N at earthing up recorded the highest dry tuber yield (4.76 t ha^{-1}), dry haulm yield (3.15 t ha^{-1}) and dry biological yield (7.92 t ha^{-1}), each significantly higher than the other treatments. The higher dry tuber yield under 50% RDF-N at planting + 50% RDF-N at earthing up was a consequence of its higher fresh tuber yield rather than a reported change in tuber dry-matter concentration. Harvest index was highest under 25% RDF-N at planting + 25% RDF-N at earthing up + one foliar N spray at 40 DAP (73.9%), followed by 25% RDF-N at planting + foliar N sprays at 25, 40 and 55 DAP (72.8%) and 25% RDF-N at planting + 25% RDF-N at earthing up (71.6%). Thus, the treatment with the highest harvest index was not the treatment with the highest total tuber yield. This distinction is important because harvest index describes partitioning of dry matter and should not be interpreted alone as an indicator of superior seed production.

Multiplication rate

50% RDF-N at planting + 50% RDF-N at earthing up recorded the highest multiplication rate by number (7.74) and by weight (7.3). The multiplication rate by number under 50% RDF-N at planting + 50% RDF-N at earthing up was significantly higher than most treatments and was statistically comparable with 50% RDF-N at planting + 25% RDF-N at earthing up + foliar N sprays at 40 and 55 DAP. The greater multiplication rate under 50% RDF-N at planting + 50% RDF-N at earthing up was consistent with its highest total tuber number and total tuber yield, indicating that the full recommended N dose supplied in two soil applications supported efficient multiplication of the planted seed tubers.

Economic performance

The cost of cultivation varied only slightly among treatments because the major variation was attributable to N fertilizer and foliar application costs. Application of 50% RDF-N at planting + 50% RDF-N at earthing up recorded the highest cost of cultivation (₹195.6 × 10^3 ha^{-1}), but the additional cost was less than compensated by its higher yield (Table 1). Consequently, 50% RDF-N at planting + 50% RDF-N at earthing up produced the highest gross return (₹510.6 × 10^3 ha^{-1}), net return (₹314.9 × 10^3 ha^{-1}) and benefit:cost (2.61). Application of 50% RDF-N at planting + 25% RDF-N at earthing up + one foliar N spray at 40 DAP ranked second for gross return (₹436.5 × 10^3 ha^{-1}), net return (₹241.5 × 10^3 ha^{-1}) and benefit: cost (2.24). The economic results therefore reinforce the agronomic results: under the experimental conditions, full recommended N applied in two soil splits provided the best combined productivity and economic outcome (John, 2017).

Table 1. Effect of nitrogen applications on economics of seed potato production (two years mean data)

Treatments	Multiplication rate		Dry tuber yield (t/ha)	Dry haulm yield (t/ha)	Dry biological yield (t/ha)	Harvest Index	Economics			
	By number	By weight					CC ('000Rs./ ha)	GR ('000Rs./ ha)	NR ('000Rs./ ha)	B:C ('000Rs./ ha)
50% RDF N + 50% RDF N	7.74	7.3	4.76	3.15	7.92	60.3	195.6	510.6	314.9	2.61
50% RDFN + 25% RDF N	6.11	5.0	3.29	1.89	5.19	63.5	195.2	353.4	158.1	1.81
25% RDFN +25% RDFN	5.94	4.7	2.80	1.13	3.93	71.6	194.8	327.1	132.3	1.68
50% RDFN + 25% RDFN + N spray at 40 DAP	6.52	6.2	3.92	1.81	5.73	68.4	194.9	436.5	241.5	2.24
25% RDFN + 25% RDFN + N spray at 40 DAP	5.59	4.6	2.97	1.06	4.03	73.9	194.8	324.9	130.1	1.67
50% RDFN + 25% RDFN + N spray at 40 & 55 DAP	6.94	6.1	3.74	2.23	5.98	63.1	195.2	426.3	231.0	2.18

Treatments	Multiplication rate		Dry tuber yield (t/ha)	Dry haulm yield (t/ha)	Dry biological yield (t/ha)	Harvest Index	Economics			
	By number	By weight					CC ('000Rs./ ha)	GR ('000Rs./ ha)	NR ('000Rs./ ha)	B:C ('000Rs./ ha)
25% RDFN + 25% RDFN + N spray at 40& 55 DAP	5.89	4.2	2.69	1.1	3.80	71.1	194.8	296.0	101.1	1.52
50% RDFN + N spray at 25, 40& 55 DAP	5.73	5.3	3.16	1.98	5.14	61.6	194.9	370.6	175.7	1.90
25% RDFN + N spray at 25, 40 & 55 DAP	5.87	4.7	2.88	1.09	3.98	72.8	194.4	330.1	135.7	1.69
Sem±	0.29	0.21	0.14	0.21	0.31	2.4	-	15.1	15.1	0.07
CD 5%	0.90	0.65	0.41	0.64	0.93	7.2	-	45.5	45.5	0.23

Implications for seed tuber production

The principal finding of the study is that N management influenced both the quantity and size profile of seed tubers. The full recommended N schedule (50% RDF-N at planting + 50% RDF-N at earthing up) maximized total tuber number and total yield and produced the highest yield of the 50–75 g and >75 g grades. Reduced soil N combined with foliar sprays did not compensate for the lower total N supplied through soil application. However, the higher harvest index under some reduced-N treatments shows that N partitioning and total productivity are not necessarily maximized by the same treatment. For practical seed potato production at the experimental site, the results support the use of 150 kg N ha^{-1} applied as 50% at planting and 50% at earthing up, provided that the same soil and crop conditions prevail.

CONCLUSION

Under the clay-loam soil and winter growing conditions of the ICAR–CPRI Regional Station, Patna, application of 150 kg N ha^{-1} as 50% at planting and 50% at earthing up was the most effective among the evaluated schedules for seed potato production. This treatment produced the highest total tuber number (645 × 10^3 ha^{-1}), total tuber yield (25.5 t ha^{-1}), multiplication rate, dry tuber and biological yields, gross and net returns, and benefit: cost. It also produced the highest yield of the 50–75 g and >75 g grades. The findings therefore support the recommended 150 kg N ha^{-1} supplied in split applications of 50% at planting and 50% at earthing up rather than reduced soil N supplemented with foliar N sprays, for maximizing seed tuber productivity under the conditions of this study.

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