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## CONSERVATION TILLAGE AND NANO NITROGEN NUTRITION ON GROWTH AND YIELD IN CHINESE POTATO

K.T. Gopika<sup>1\*</sup> and Sheeba Rebecca Isaac<sup>2</sup>

<sup>1</sup>College of Agriculture, Vellayani, Thiruvananthapuram (Kerala Agricultural University), Kerala, India

<sup>2</sup>Regional Agricultural Research Station, Kumarakom, Kottayam- 686 563, Kerala, India

\*Corresponding author E-mail: [gopikaravi26.8.1998@gmail.com](mailto:gopikaravi26.8.1998@gmail.com)

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### ABSTRACT

The field experiment was conducted to assess the influence of tillage practices and nano nitrogen nutrition on the growth and yield in Chinese potato at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala Agricultural University in 2022-23. The experiment was laid out in split plot design with three replications. The main plot treatments included conventional tillage, reduced tillage (RT) with surface incorporation of green manure cowpea and RT with surface retention of green manure cowpea and the sub plot treatments, different doses of nitrogen along with foliar spray of nano urea at 0.4 per cent concentration. The results revealed the significant influence of reduced tillage and nano urea individually on growth attributes and yield in Chinese potato. Among the interactions, RT + *in situ* green manuring and nano urea spray +50 per cent RDF revealed higher values for plant height at 30 and 60 DAP, plant spread at all growth stages, tuber yield (17.74 t ha<sup>-1</sup>) and uptake of N, P and K.

**Key words:** Conservation tillage, reduced tillage, green manure, nano urea, Chinese potato

### Introduction

Conservation agriculture (CA) represents a paradigm shift in farming practices aimed at promoting sustainable agricultural systems that mitigate greenhouse gas emissions while enhancing productivity and resilience. With growing concerns about climate change and its impacts on agricultural productivity, there's an increasing recognition of the need to adopt practices that contribute to greenhouse gas (GHG) mitigation in the agricultural sector. Conservation agriculture encompasses a set of principles and practices that focus on minimal soil disturbance, permanent soil cover, and diversified crop rotations (IPCC, 2013). Conservation tillage helps to preserve soil structure and organic matter, which in turn enhances soil carbon sequestration capacity. The use of permanent soil cover, such as crop residues or cover crops, reduces soil erosion, enhances water retention, and promotes biodiversity, all of which contribute to the mitigation of GHGs.

The use of chemical fertilizers in agriculture has aggravated the degradation of soil characteristics and

also intensified the occurrence of eutrophication and environmental contamination. Exploration for feasible substitutes has instigated the development of nano-fertilizers, which offer the advantage of fulfilling the nutrient necessities at with reduced doses. Transitioning away from conventional fertilizers towards nano-fertilizers represents a critical step towards sustainable agriculture, offering solutions to address environmental, economic, and social challenges associated with conventional fertilizer use (Dutta, 2022). Liquid nano urea, developed by the Indian Farmers Fertilizer Cooperative Limited (IFFCO), serves as an alternative to conventional urea for fulfilling N needs of the crop, particularly during critical growth phases (Lakshman *et al.*, 2022). Foliar application of nano urea facilitates the effective absorption and penetration of N into the leaves. Moreover, it releases nutrients gradually, minimizing environmental wastage.

Chinese potato [*Plectranthus rotundifolius* (Poir.) Spreng.], also called hausa potato and country potato, though a minor tuber crop, owing to its shorter duration and high biological efficiency, has immense potential to

be included in the cropping systems of Kerala. As in the case of all tuber crops, the primary economic activity in Chinese potato takes place beneath the soil surface and hence adoption of CA practices can have a favourable impact on both above- ground growth and tuberization. When integrated with the practice of mulching or residue incorporation, RT serves as a mechanism for C sequestration in soil, serving as a C sink and augmenting nutrient availability (Lal, 2008). Further the canopy cover with establishment is almost 100 per cent which appeases foliar nutrition with minimum soil fall.

Keeping this in view, an experiment was attempted to assess the influence of tillage and nano nitrogen on the growth and yield of Chinese potato.

### Materials and Methods

The field experiment was conducted at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala Agricultural University in 2022-23. The site enjoys a warm humid tropical climate, and during the cropping period received a total rainfall of 42.60 mm. The maximum temperature ranged from of 31°C to 34°C and the minimum temperature, 18°C to 24°C. Based on USDA taxonomic system, the soil was classified as sandy clay loam in texture and was medium in organic C (1.05%), available N (300.70 kg ha<sup>-1</sup>) and available K (192.64 kg ha<sup>-1</sup>), and high in available P (38.67 kg ha<sup>-1</sup>).

The experiment was laid out in split plot design with three methods of tillage as main plot treatments [conventional tillage (c<sub>1</sub>), RT+ surface incorporation of GM cowpea (c<sub>2</sub>) and RT + surface retention of GM cowpea (c<sub>3</sub>)] and four levels of N management [100% RDN+ nano urea (n<sub>1</sub>), 75% RDN + nano urea (n<sub>2</sub>), 50% RDN + nano urea (n<sub>3</sub>) and 100% recommended dose of fertilizers (RDF) (n<sub>4</sub>)] as sub plot treatments in three replications. In RT, after initial basal ploughing, the secondary ploughing was done in the row zone alone. The cowpea variety Aiswarya was sown in reduced till plots as green manure crop @ 20 kg seeds ha<sup>-1</sup>, during the first week of December 2022. At flowering stage, the cowpea plants were incorporated/ retained as surface mulch as per treatments. Stem cuttings of Chinese potato variety Suphala were planted in the field two weeks after green manure application at a spacing of 30 cm × 15 cm.

Foliar spray of nano urea @ 4 mL L<sup>-1</sup> was given twice, at 20 and 40 DAP. Nutrient management was done @ 60 :60 :100 kg ha<sup>-1</sup> of N, P and K, the recommended dose and the entire dose of P applied as basal, N and K, in two equal splits, basal and 45 days after planting (DAP). Growth attributes viz., plant height, spread, number of branches, leaf area per plant and dry matter

production of the crop were observed at 30 days interval. Crop was harvested at 140 DAP, yields were recorded. Nutrient uptake was computed based on the nutrient content and dry matter production in each treatment. The data were subjected to ANOVA and wherever significant, critical difference was used to assess the treatment effects.

## Results and Discussion

### Growth attributes

The influence of CT and nano urea was not found prominent on the plant height, number of branches per plant and plant spread at the early stages of growth, while significant variations were recorded in plant height and number of branches produced as growth advanced (Table 1a and 1b). The values were significantly higher in the practice of RT with the incorporation of cowpea biomass(c<sub>2</sub>). The treatment RT + surface incorporation of GM cowpea resulted in significantly taller plants (18.68 and 21.32 cm) at 90 and 120 DAP respectively, higher number of branches per plant (10.82) at 120 DAP and superior leaf area per plant at 30, 60 and 120 DAP.

Stem cuttings of Chinese potato were planted two weeks after cowpea incorporation/ mulching and hence it is assumed that the decomposition and mineralization would have taken time to bring about significant variations in the plant growth during the early stages. However, the values remained comparatively higher for the RT treatments than in the conventional tillage bringing to light the positive influence of the additional organic matter accrued through GM residues. The effects were pronounced two months after planting and it is inferred that favourable effects on the soil properties; moisture retention, aggregation, fertility and microbial activity, would have influenced the growth attributes.

Sarangi *et al.*, (2020) reported better growth attributes in potato crop under ZT with paddy straw mulch, compared to the conventional ridge planted potato crop and ascribed this to the increased soil moisture conservation and organic C content. Ozbolat *et al.*, (2023) also documented that RT and GM application could improve soil physical, chemical and biological properties leading to increased soil C and N contents, which are beneficial for plant growth.

Leaf area remained significantly the highest in the treatment of RT + surface incorporation of cowpea biomass at all stages of growth followed by c<sub>3</sub>, RT with surface retention of cowpea. The values were maximum at 90 DAP and thereafter, declined with senescence. The legume effects and organic matter addition would have had a positive impact on the plant growth in c<sub>2</sub> and c<sub>3</sub>

**Table 1a:** Effect of tillage and nutrient management on growth attributes.

| Treat-<br>ment      | Plant height<br>(cm) |           |           |            | Number of<br>branches |           |           |            | Plant spread<br>(cm) |           |           |            | Leaf area per<br>plant (cm <sup>2</sup> ) |           |           |            | Dry matter production<br>(g per plant) |           |           |            |
|---------------------|----------------------|-----------|-----------|------------|-----------------------|-----------|-----------|------------|----------------------|-----------|-----------|------------|-------------------------------------------|-----------|-----------|------------|----------------------------------------|-----------|-----------|------------|
|                     | 30<br>DAP            | 60<br>DAP | 90<br>DAP | 120<br>DAP | 30<br>DAP             | 60<br>DAP | 90<br>DAP | 120<br>DAP | 30<br>DAP            | 60<br>DAP | 90<br>DAP | 120<br>DAP | 30<br>DAP                                 | 60<br>DAP | 90<br>DAP | 120<br>DAP | 30<br>DAP                              | 60<br>DAP | 90<br>DAP | 120<br>DAP |
| <b>Tillage</b>      |                      |           |           |            |                       |           |           |            |                      |           |           |            |                                           |           |           |            |                                        |           |           |            |
| c <sub>1</sub>      | 12.41                | 13.74     | 16.84     | 19.85      | 12.47                 | 14.15     | 16.15     | 10.12      | 26.62                | 28.38     | 31.39     | 25.16      | 787.9                                     | 942.85    | 1013.42   | 559.31     | 15.06                                  | 23.84     | 49.7      | 64.19      |
| c <sub>2</sub>      | 12.73                | 14.4      | 18.68     | 21.32      | 13.3                  | 14.68     | 17.8      | 10.82      | 27.7                 | 29.56     | 31.75     | 26.06      | 913.79                                    | 1026.93   | 1143.09   | 724.13     | 17.49                                  | 26.31     | 51.83     | 66         |
| c <sub>3</sub>      | 12.63                | 14.08     | 16.68     | 19.38      | 14.79                 | 16.25     | 16.87     | 10.27      | 28.88                | 30.69     | 30.27     | 24.51      | 864.36                                    | 1010.16   | 1083.74   | 585.46     | 15.98                                  | 24.57     | 49.24     | 62.85      |
| SE<br>(m)(±)        | 0.58                 | 0.76      | 0.52      | 0.16       | 0.73                  | 0.64      | 0.42      | 0.124      | 1.65                 | 1.55      | 0.64      | 0.31       | 12.25                                     | 6.36      | 35.82     | 20.02      | 0.83                                   | 1.5       | 3.51      | 4.11       |
| CD<br>(0.05)        | NS                   | NS        | 1.44      | 0.623      | NS                    | NS        | NS        | 0.486      | NS                   | NS        | NS        | NS         | 48.114                                    | 24.986    | NS        | 78.614     | NS                                     | NS        | NS        | NS         |
| <b>N management</b> |                      |           |           |            |                       |           |           |            |                      |           |           |            |                                           |           |           |            |                                        |           |           |            |
| n <sub>1</sub>      | 12.05                | 13.49     | 16.36     | 19.29      | 13.32                 | 14.97     | 17.72     | 10.67      | 27.25                | 28.92     | 30.51     | 24.16      | 914.94                                    | 1041.09   | 1136.93   | 720.37     | 17.31                                  | 26.17     | 52.59     | 67.02      |
| n <sub>2</sub>      | 12.58                | 13.97     | 19.17     | 22.1       | 13.36                 | 15.25     | 17.17     | 10.41      | 27.37                | 29.01     | 29.53     | 25.02      | 884.7                                     | 1018.06   | 1109.17   | 658.72     | 17.18                                  | 26.37     | 51.92     | 66.56      |
| n <sub>3</sub>      | 13.76                | 15.83     | 17.73     | 20.73      | 15.1                  | 16.09     | 16.74     | 10.37      | 30.47                | 32.78     | 34.99     | 27.01      | 847.95                                    | 987.78    | 1065.14   | 591.57     | 16.52                                  | 24.82     | 50.02     | 63.75      |
| n <sub>4</sub>      | 11.98                | 13.01     | 16.34     | 18.63      | 12.28                 | 13.8      | 16.12     | 10.17      | 25.85                | 27.45     | 29.51     | 24.79      | 773.81                                    | 926.33    | 1009.09   | 521.21     | 13.69                                  | 22.28     | 46.51     | 60.06      |
| SE<br>(m)(±)        | 0.42                 | 0.45      | 0.43      | 0.48       | 0.51                  | 0.65      | 0.38      | 0.18       | 0.79                 | 0.75      | 0.57      | 0.46       | 9.36                                      | 12.82     | 17.65     | 10.67      | 1.06                                   | 1.65      | 3.41      | 4.48       |
| CD<br>(0.05)        | 1.25                 | 1.34      | 0.911     | 1.423      | 1.516                 | NS        | NS        | NS         | 2.34                 | 2.234     | 1.698     | 1.375      | 27.797                                    | 38.101    | 52.44     | 31.711     | NS                                     | NS        | NS        | NS         |

compared to the plants in conventional tillage. Between the two conservation practices, loosening of top soil on the beds + incorporation would have enhanced rooting and better availability and absorption of nutrients favouring leaf development and hence a better leaf area. In their study, Fasinmirin and Reichert (2011) observed that the combined impacts of soil and water conservation and lowered soil temperature with the residue cover under NT could enhance the above-ground biomass development in cassava.

Among the N management practices, the treatment of 50 per cent RDN with foliar application of nano urea recorded the maximum above -ground growth, followed by 75 per cent RDN and nano urea. Significantly taller plants at 30 and 60 DAP, plant spread (30.47, 32.78 and 34.99 cm, respectively) at 30, 60 and 90 DAP and the significantly highest number of branches (15.10) at 30 DAP were recorded in n<sub>3</sub> (50 % RDN + nano urea). Plants were significantly taller at 90 DAP and 120 DAP in n<sub>2</sub> (75 % RDN+ nano urea). Phosphorus and K dose remaining the same, the efficiency of nano urea has been well illustrated in the study. All growth attributes, plant height, plant spread, number of branches and leaf area were significantly greater in nano urea application compared to the RDF without nano urea (n<sub>4</sub>). It is also evident that with the inclusion of nano urea, the RDN could be reduced by 50 per cent. The advantages of nano urea are attributed to the unique properties of nano urea viz., small particle size (20-50 nm), large surface area and the presence of more reactive oxygen that enhances the photosynthetic rate and metabolic activities (Nibin, 2019). Similar reports of 50 per cent RDN with nano urea sprays recording higher values for plant height, root length and tuber production in potatoes have been reported (Dutta, 2022; Manikanta *et al.*, 2023). Nano urea has the advantages of steady supply of N and faster leaf absorption and hence its application as foliar spray ensures better nutrient use efficiency than when soil applied. DeRosa *et al.*, (2020) reported that nano fertilizers can increase the growth and yield of crops as they facilitate the nutrient release in a manner that ensures the crop the exact amount of nutrients in the right proportions.

**Table 1b:** Interaction effect of tillage and nutrient management on growth attributes.

| Treat-<br>ment                | Plant height<br>(cm) |       |       |       | Number of<br>branches |       |       |       | Plant spread<br>(cm) |       |       |       | Leaf area per<br>plant (cm <sup>2</sup> ) |         |         |        | Dry matter production<br>(g per plant) |       |       |       |
|-------------------------------|----------------------|-------|-------|-------|-----------------------|-------|-------|-------|----------------------|-------|-------|-------|-------------------------------------------|---------|---------|--------|----------------------------------------|-------|-------|-------|
|                               | 30                   |       | 60    |       | 90                    |       | 120   |       | 30                   |       | 60    |       | 90                                        |         | 120     |        | 30                                     |       | 60    |       |
|                               | DAP                  | DAP   | DAP   | DAP   | DAP                   | DAP   | DAP   | DAP   | DAP                  | DAP   | DAP   | DAP   | DAP                                       | DAP     | DAP     | DAP    | DAP                                    | DAP   | DAP   | DAP   |
| C <sub>1</sub> N <sub>1</sub> | 13.33                | 14.60 | 15.77 | 19.57 | 12.20                 | 13.98 | 16.93 | 10.53 | 26.43                | 28.42 | 32.73 | 24.70 | 878.04                                    | 1005.10 | 1081.80 | 664.44 | 15.15                                  | 23.28 | 47.02 | 59.60 |
| C <sub>1</sub> N <sub>2</sub> | 13.21                | 14.72 | 18.63 | 21.49 | 13.00                 | 14.67 | 15.13 | 9.72  | 28.05                | 29.45 | 29.53 | 24.98 | 831.10                                    | 983.03  | 1036.25 | 574.41 | 13.92                                  | 22.34 | 44.53 | 57.69 |
| C <sub>1</sub> N <sub>3</sub> | 11.89                | 13.56 | 16.87 | 20.11 | 13.45                 | 15.07 | 16.90 | 10.71 | 27.67                | 29.89 | 34.17 | 26.13 | 776.28                                    | 939.37  | 985.95  | 515.28 | 17.61                                  | 27.92 | 58.27 | 74.64 |
| C <sub>1</sub> N <sub>4</sub> | 11.19                | 12.08 | 16.10 | 18.24 | 11.22                 | 12.88 | 15.63 | 9.54  | 24.33                | 25.76 | 29.13 | 24.85 | 666.19                                    | 843.92  | 949.69  | 483.10 | 13.54                                  | 21.83 | 48.98 | 64.84 |
| C <sub>2</sub> N <sub>1</sub> | 10.93                | 12.37 | 17.70 | 20.30 | 11.78                 | 13.49 | 18.40 | 11.16 | 25.36                | 26.96 | 27.33 | 24.46 | 950.91                                    | 1065.06 | 1181.26 | 787.05 | 17.94                                  | 26.54 | 52.63 | 67.57 |
| C <sub>2</sub> N <sub>2</sub> | 12.64                | 13.82 | 21.27 | 24.40 | 13.87                 | 16.17 | 20.50 | 11.36 | 27.64                | 29.37 | 32.20 | 25.62 | 940.77                                    | 1031.78 | 1170.63 | 769.47 | 19.29                                  | 28.43 | 54.83 | 70.47 |
| C <sub>2</sub> N <sub>3</sub> | 14.94                | 17.93 | 18.50 | 21.10 | 16.33                 | 16.40 | 16.60 | 10.25 | 32.87                | 35.40 | 37.60 | 30.08 | 916.37                                    | 1031.86 | 1157.95 | 734.84 | 17.90                                  | 26.28 | 50.45 | 63.66 |
| C <sub>2</sub> N <sub>4</sub> | 12.42                | 13.47 | 17.23 | 19.50 | 11.21                 | 12.65 | 15.70 | 10.51 | 24.93                | 26.50 | 29.87 | 24.07 | 847.09                                    | 979.02  | 1062.51 | 605.14 | 14.84                                  | 24.00 | 49.40 | 62.31 |
| C <sub>3</sub> N <sub>1</sub> | 11.89                | 13.50 | 15.60 | 17.99 | 15.98                 | 17.43 | 17.83 | 10.32 | 29.97                | 31.39 | 31.47 | 23.31 | 915.88                                    | 1053.10 | 1147.73 | 709.61 | 18.83                                  | 28.70 | 58.11 | 73.88 |
| C <sub>3</sub> N <sub>2</sub> | 11.89                | 13.36 | 17.60 | 20.40 | 13.21                 | 14.90 | 15.87 | 10.15 | 26.41                | 28.22 | 26.87 | 24.45 | 882.22                                    | 1039.39 | 1120.63 | 632.26 | 18.33                                  | 28.33 | 56.39 | 71.52 |
| C <sub>3</sub> N <sub>3</sub> | 14.44                | 15.99 | 17.83 | 20.98 | 15.53                 | 16.80 | 16.73 | 10.16 | 30.87                | 33.05 | 33.20 | 24.81 | 851.19                                    | 992.11  | 1051.53 | 524.58 | 14.06                                  | 20.24 | 41.33 | 52.95 |
| C <sub>3</sub> N <sub>4</sub> | 12.32                | 13.48 | 15.70 | 18.16 | 14.42                 | 15.88 | 17.03 | 10.45 | 28.29                | 30.10 | 29.53 | 25.46 | 808.16                                    | 956.05  | 1015.06 | 475.38 | 12.70                                  | 21.01 | 41.14 | 53.03 |
| SE (m)                        |                      |       |       |       |                       |       |       |       |                      |       |       |       |                                           |         |         |        |                                        |       |       |       |
| A/B (±)                       | 0.73                 | 0.78  | 0.75  | 0.83  | 0.88                  | 1.12  | 0.66  | 0.66  | 1.36                 | 1.30  | 0.99  | 0.80  | 16.20                                     | 22.21   | 30.57   | 18.49  | 1.83                                   | 2.86  | 5.91  | 7.75  |
| SE (m)                        |                      |       |       |       |                       |       |       |       |                      |       |       |       |                                           |         |         |        |                                        |       |       |       |
| B/A (±)                       | 0.86                 | 1.02  | 0.83  | 0.74  | 1.06                  | 1.16  | 0.71  | 0.30  | 2.03                 | 1.92  | 1.07  | 0.76  | 18.63                                     | 20.26   | 44.54   | 25.64  | 1.79                                   | 2.90  | 6.20  | 7.87  |
| CD<br>(0.05)<br>A/B           | 2.166                | 2.327 | NS    | NS    | NS                    | NS    | 1.972 | 0.903 | NS                   | NS    | 2.941 | 2.382 | 48.146                                    | NS      | NS      | 54.925 | NS                                     | NS    | NS    | NS    |
| CD<br>(0.05)<br>B/A           | 2.915                | 3.559 | NS    | NS    | NS                    | NS    | 2.363 | 0.914 | NS                   | NS    | 3.554 | 2.385 | 63.053                                    | NS      | NS      | 91.105 | NS                                     | NS    | NS    | NS    |

Leaf area per plant was the highest in the treatment, 100 per cent RDN + nano urea at 30, 60, 90 and 120 DAP and it was significantly superior at 30 and 120 DAP, 914.94 and 720.37 cm<sup>2</sup> respectively. Nitrogen is the most important nutrient for canopy development and its outcomes include enhanced vegetative growth and photosynthetic efficiency. It is a crucial component of numerous molecules including chlorophyll, deoxyribonucleic acid (DNA), amino acids, proteins and adenosine triphosphate (ATP), plays a significant role in synthesis of tryptophan, an amino acid for production of auxin which in turn helps in cell division and cell expansion (Abd-Alquader *et al.*, 2020). In n<sub>1</sub>, the amount of N made available to the crop is 25 to 100 per cent higher than that in the remaining treatments and Chinese potato plants in n<sub>1</sub> responded to the additional N received in terms of its improved leaf area. The data on the highest N uptake in this treatment also bears testimony to this observation. However, a balanced NPK application is always beneficial for crop growth (DeRosa *et al.*, 2020) and this would be the reason for the lower doses of N along with nano urea to record on par values.

The individual effects of tillage and N management were reflected in the interactions. The combination of RT + surface incorporation of GM cowpea and N management with 50 per cent RDN + nano urea resulted in significantly taller plants with better plant spread at 30 and 60 DAP and with 75 per cent RDN + nano urea at 60 and 90 DAP, while the leaf area was the highest in c<sub>2</sub>n<sub>1</sub> (RT + surface incorporation of GM cowpea + 100% RDN + nano urea).

### Yield

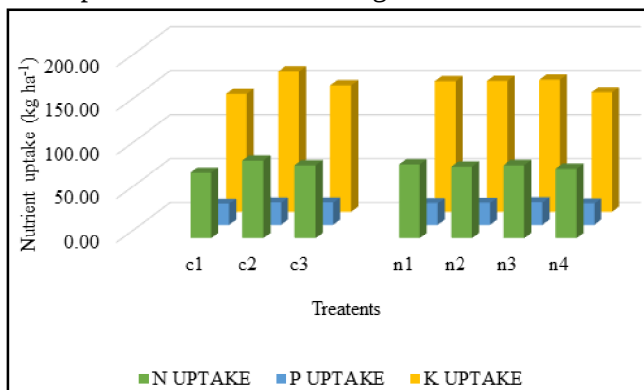
The variations in tuber yield due to the treatments are presented in Tables 2a and 2b. There was no marked variations in the tuber yield per plant under different methods of tillage but was comparatively higher with RT. Nevertheless, the marketable tuber yield, tubers weighing more than 5 g (130.67 g per plant) was

**Table 2a:** Influence of tillage methods and N management on tuber yields in Chinese potato.

| Treat-ments         | Total tuber yield (g per plant) | Marketable tuber yield (g per plant) |
|---------------------|---------------------------------|--------------------------------------|
| <b>Tillage</b>      |                                 |                                      |
| c <sub>1</sub>      | 136.68                          | 87.17                                |
| c <sub>2</sub>      | 166.87                          | 130.67                               |
| c <sub>3</sub>      | 163.37                          | 116.01                               |
| SE (m) (±)          | 8.09                            | 6.21                                 |
| CD (0.05)           | NS                              | 24.373                               |
| <b>N management</b> |                                 |                                      |
| n <sub>1</sub>      | 152.83                          | 115.29                               |
| n <sub>2</sub>      | 160.38                          | 120.94                               |
| n <sub>3</sub>      | 168.12                          | 117.54                               |
| n <sub>4</sub>      | 141.23                          | 91.37                                |
| SE (m) (±)          | 5.97                            | 5.89                                 |
| CD (0.05)           | 17.727                          | 17.505                               |

significantly higher in reduced tillage + surface incorporation of GM cowpea (c<sub>2</sub>) and on par with c<sub>3</sub> (RT + surface retention of GM cowpea), 116.01 g per plant.

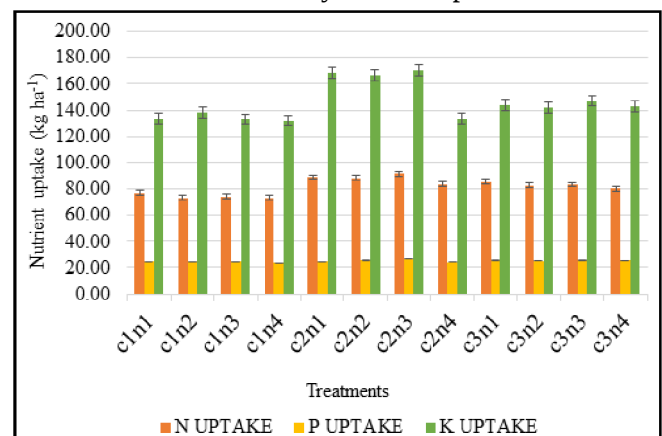
Reduced tillage minimizes the disturbances in soil and this is not generally ideal for tuber bulking. Nevertheless, coupled with conservation practices of mulching/ organic matter accretions, the soil properties can be modified to make them amenable for tuber development. In the present study, land preparation was confined to initial ploughing and secondary tillage at row zone alone, along with *in situ* green manuring with cowpea. The incorporation can provide some amount of tilling to loosen the soil, and consequent green matter decomposition and microbial activity can make it friable for tuber formation and bulking. Further, Chinese potato is a shallow rooted crop, the maximum depth of tuber formation being 30 cm. Tuber bulking in the crop was seen after 60 DAP which coincided with the time of peak period of decomposition in green manure cowpea (6-8 weeks) (Das *et al.*, 2020), which would have contributed to better soil aggregation and nutrient release that favoured tuber development. Conventional tillage leads to inversion and

**Fig. 1a:** Effect of treatments on nutrient uptake, kg ha<sup>-1</sup>.**Table 2b:** Interaction effect of method of tillage and N management on tuber yield in Chinese potato.

| Treat-ments                   | Total tuber yield (g per plant) | Marketable tuber yield (g per plant) |
|-------------------------------|---------------------------------|--------------------------------------|
| c <sub>1</sub> n <sub>2</sub> | 126.95                          | 91.14                                |
| c <sub>1</sub> n <sub>2</sub> | 126.66                          | 84.63                                |
| c <sub>1</sub> n <sub>3</sub> | 148.32                          | 97.07                                |
| c <sub>1</sub> n <sub>4</sub> | 144.81                          | 75.85                                |
| c <sub>2</sub> n <sub>1</sub> | 160.12                          | 125.03                               |
| c <sub>2</sub> n <sub>2</sub> | 174.37                          | 146.91                               |
| c <sub>2</sub> n <sub>3</sub> | 181.89                          | 142.02                               |
| c <sub>2</sub> n <sub>4</sub> | 137.11                          | 108.71                               |
| c <sub>3</sub> n <sub>1</sub> | 171.41                          | 129.69                               |
| c <sub>3</sub> n <sub>2</sub> | 180.12                          | 131.27                               |
| c <sub>3</sub> n <sub>3</sub> | 174.16                          | 113.53                               |
| c <sub>3</sub> n <sub>4</sub> | 141.78                          | 89.54                                |
| SE (m) A/B(±)                 | 10.33                           | 10.20                                |
| SE (m) B/A(±)                 | 12.06                           | 10.80                                |
| CD (0.05) A/B                 | NS                              | NS                                   |
| CD (0.05) B/A                 | NS                              | NS                                   |

loosening the soil but the advantages of an enhanced soil fertility with the legume and green manure effects were lacking. The total tuber yield was comparable in all tillage methods however the proportion of larger sized tubers which has consumer preference were greater in reduced tillage treatments.

Among the N management practices, tuber yield per plant was the highest (168.12g) at 50 per cent RDN+ nano urea (n<sub>3</sub>) and on par with n<sub>2</sub> (160.38 g). The lowest per plant yield (152.83 g) was recorded by n<sub>4</sub> (100 per cent RDF). Application of 75% RDN + nano urea (n<sub>2</sub>) yielded higher marketable tubers (120.97 g per plant) which was comparable with n<sub>3</sub> (50% RDN + nano urea) and n<sub>1</sub> (100% RDN + nano urea) with marketable tuber yield of 117.54 and 115.29 g per plant respectively. This brings to focus the possibility of reducing the recommended dose of N by 25 to 50 per cent.

**Fig. 1b:** Interaction effect of treatments on nutrient uptake, kg ha<sup>-1</sup>.

The positive influence of foliar application of nano urea is very evident in the study. As explained earlier, the foliar application would have enhanced nutrient absorption, facilitating rapid nutrient transportation and delivery through plasmodesmata (Mahanta *et al.*, 2019). The availability at the target sites favourably influenced canopy development, the source strength for photosynthesis. Potassium the major nutrient influencing translocation was applied as per the recommendation for the crop and hence it is assumed that the balanced application ensued a source- sink balance ideal for tuber development and bulking. However, the interaction effect was not significant.

### Nutrient uptake

Nutrient uptake is the product of the amount of dry matter and the concentration of nutrient present in the tissue. As illustrated in Fig. 1, the treatment, RT + surface incorporation of GM cowpea ( $c_2$ ) recorded a higher N uptake which was on par with  $c_3$  (RT + surface retention of GM cowpea). Phosphorus uptake was the highest in  $c_3$  and it was on par with  $c_2$ . The significantly highest K uptake was recorded by  $c_2$ . The favourable effects of RT observed in growth and yield with better nutrient absorption contributed to the higher DMP and hence the uptake.

Application of 100 per cent RDN + nano urea ( $n_1$ ) recorded significantly superior N uptake. In the case of P, the uptake was 25.62 kg ha<sup>-1</sup> in 50 per cent RDN + nano urea comparable with 75 per cent RDN + nano urea, 25.05 kg ha<sup>-1</sup>. The treatment 50 per cent RDN + nano urea recorded the highest K uptake. Hayyawi *et al.*, (2019) in their study documented enhanced nutrient uptake in potato, attributable to the increased DMP in terms of both fresh and dry vegetative yield with foliar application of nano fertilizers.

The cumulative effect of the treatments was observed in the combination of RT + with nano urea and the uptake of N, P and K were the highest in  $c_2n_3$ .

### Conclusion

The study brings to light the significant influence of conservation tillage practices on the growth and tuber yield in Chinese potato. Reduced tillage and GM cowpea application along with foliar spray of nano N resulted in better growth and higher marketable tuber yield and is assumed would be more ecofriendly on account of the minimized soil disturbance and reduced inorganic N application in soil.

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