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RESEARCH ARTICLE

Dry Matter Accumulation and Nutrient Acquisition of Summer Irrigated Greengram (*Vigna radiata* L.) as Influenced by Integrated Application of Basal Nitrogen and Foliar Feeding of Nano and Conventional Urea

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ABSTRACT

A field experiment was conducted at wetland farm of Tamil Nadu Agricultural University, Coimbatore, during the summer of 2022 to study the influence of different levels of basal nitrogen in combination with foliar fertilization of various concentrations of nano and conventional urea on dry matter production, nutrient uptake of green gram and post-harvest availability of soil nutrients. The experiment was framed in a factorial randomized block design comprising of two factors (N and F) with four levels under each factor. Basal nitrogen levels *viz*., N_1 - 100% RDN (25 kg N ha^{-1}), N_2 - 80% RDN (20 kg N ha^{-1}), N_3 - 60% RDN (15 kg N ha^{-1}) and N_4 - Absolute nitrogen control (0 kg N ha^{-1}) were assigned under factor N. Likewise, foliar nutrition practices *viz*., F_1 - Nano urea @ 2 mL $litre^{-1}$ of water, F_2 - Nano urea @ 3 mL $litre^{-1}$ of water, F_3 - Nano urea @ 4 mL $litre^{-1}$ of water, F_4 - 1% conventional urea were assigned under factor F which were sprayed at flower initiation (FI) stage and 15 days thereafter. All the treatment combinations were replicated thrice. The results of the field experiment indicated that basal application of 100% and 80% RDN in combination with foliar spray of nano urea @ 4 mL $litre^{-1}$ of water at FI stage and 15 days thereafter significantly recorded the maximum dry matter production and higher uptake of nitrogen, phosphorus, and potassium. As the performance of both the treatment combinations was almost comparable, the adoption of reduced dose, *i.e*., application of 80% RDN integrated with foliar feeding of nano urea @ 4 mL $litre^{-1}$ of water at FI stage and 15 days thereafter, would be effective in maximizing the dry matter production and nutrient uptake by greengram.

Keywords: Basal Nitrogen, Dry Matter Production, Greengram, Nano Urea, Nutrient Uptake

INTRODUCTION

Pulses are portrayed as one of the most essential and inevitable crop components in the present and future day cropping and farming systems because of their excellent benefits to the agro-ecosystem like the ability to fix atmospheric nitrogen, addition of organic matter to the soil, enriching the soil biota, ability to

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smother weeds, *etc* (Deol *et al.*, 2018). Greengram or mungbean or golden gram is highly valued because of its excellent nutritive benefits and has a protein content of 24-25%. In India, greengram is cultivated in an area of around 5.55 Mha, accounting to the total production of 3.166 MT with an average productivity of 570 kg ha^{-1}. It is largely cultivated in the states of Rajasthan, Madhya Pradesh, Karnataka and Maharashtra (Indiastat, 2024). The main problem attributed in the cultivation of greengram is flower abortion and flower shedding which can be alleviated by foliar nutrition of essential nutrients and plant growth regulators at critical stages of the crop *viz*., flower initiation and peak flowering stages, which helps in synchronized flowering and pod setting as it efficiently translocate the essential nutrients from foliage to all the plant parts in general and reproductive parts in specific thus improving the plant's nutrient status as well as the quality of seeds (Pooja and Ameena, 2021). Foliar feeding of nutrients at critical stages of the crop has several advantages like maximum nutrient use efficiency, enhancing the plant nutrient status, minimum fertilizer requirement, reduction in cost of cultivation, alleviating the nutritional deficiencies of plants, *etc*. However, foliar fertilization can only act as a supplement to soil application of nutrients and not as its proper substitute, which is a very basic criteria for crop nutrition and its management. Therefore, the right combination and the right quantity of fertilizer have to be evolved, and it should be applied integrally as soil and foliar nutrition at the right stages of the crop for realizing the maximum biomass yield and nutrient uptake by greengram. In recent times, Indian Farmers Fertilizer Cooperative Limited (IFFCO) had developed and released a revolutionary product named 'Nano Urea' in liquid formulation in the Indian fertilizer market. This nano urea liquid fertilizer is believed to supplement necessary nitrogen nutrition to the crop, when it is applied as foliar spray at critical stages of crops. With this background, an attempt was made to integrate basal nitrogen with foliar nutrition of nano and conventional urea to evaluate their combined effect on dry matter production and nutrient uptake of summer irrigated greengram.

MATERIALS AND METHODS

Field trial was conducted at wetland farm of Tamil Nadu Agricultural University, Coimbatore during the summer (March - May) 2022 for enhancing the biomass accumulation and improving the uptake of applied nutrients by greengram through integrated nitrogen nutrient management approaches. The experimental area was located at 11° N latitude and 77° E longitude with an altitude of 426.7 m above MSL falling under the category of western agro-climatic zone of Tamil Nadu and southern agro-climatic zone of India. The mean maximum and minimum temperature recorded during the cropping period were 34.5°C and 23.6°C respectively, with an average morning RH (relative humidity) of 82.7% and an average evening RH of 45.6%. A rainfall of around 57.9 mm was registered during the cropping period. The soil type of the experimental field was clay loam, with a pH of 8.19 and EC of 0.42 dSm^{-1} (1:2.5 soil and water suspension solution). The soil of the experimental field was low in available nitrogen content (224.0 kg ha^{-1} - alkaline permanganate method), medium in available phosphorus content (16.4 kg ha^{-1} - Olsen method), and high in available potassium content (879.0 kg ha^{-1} - neutral normal ammonium acetate method) with organic carbon content of 0.66% (chromic acid wet digestion method). The field study was laid out in Factorial Randomized Block Design (FRBD) consisting of two factors *viz*., varied levels of basal nitrogen (Factor I) and foliar fertilization of nano and conventional urea at different concentrations (Factor II). Each factor comprises four levels. Under factor I, the following basal nitrogen levels *viz*., N_1 - 100% Recommended dose of nitrogen (RDN) (25 kg N ha^{-1}), N_2 - 80% RDN (20 kg N ha^{-1}), N_3 - 60% RDN (15 kg N ha^{-1}) and N_4 - Absolute nitrogen control (0 kg N ha^{-1}) were assigned. Similarly, under factor II, the following foliar feeding practices *viz*., F_1 - Nano urea @ 2 mL $litre^{-1}$ of water at Flower Initiation (FI) stage and 15 days thereafter, F_2 - Nano urea @ 3 mL $litre^{-1}$ of water at FI stage and 15 days thereafter, F_3 - Nano urea @ 4 mL $litre^{-1}$ of water at FI stage and 15 days thereafter, F_4 - 1% urea (conventional fertilizer) at FI stage and 15 days thereafter were assigned. All the treatment combinations (Factor I x Factor II) were replicated thrice. Besides the experimental treatments, basal application of phosphorus (50 kg P_2O_5 kg ha^{-1}) and potassium (25 kg K_2O ha^{-1}) were applied uniformly to all the experimental plots. Gross and net plot sizes of 4.0 m x 4.0 m and 2.8 m x 3.6 m, respectively, were adopted in the study. Certified seeds of greengram variety CO 8 were used in the experiment. The seeds were treated with bioferilizers *viz*., *Rhizobium* and

Phosphobacteria and a bio-control agent, *Bacillus subtilis*, as per the recommendation, and they were sown in lines by adopting the recommended row and plant spacing of 30 cm x 10 cm, respectively, with seed rate of 20 kg ha^{-1}. As per the treatment schedule, to impose treatment factor I, the required quantity of urea fertilizer was weighed and applied basally at the time of sowing. Similarly, for imposing the treatment factor II, the required quantity of nano urea and conventional urea were measured and thoroughly mixed with the recommended spray volume (500 liters of water ha^{-1}). For effective and efficient absorption of foliar nutrients, foliar spray of nutrients was carried out during the morning hours (before 9 AM). The crop was irrigated five times from sowing to harvest in addition to the supplemental rainfall. Suitable plant protection measures were adopted to control pests and diseases.

For recording the dry matter production, five plants were randomly plucked from the sampling rows and were shade-dried initially, and then they were placed in the hot air oven and dried at 65±5 °C until a constant weight was obtained. The weight was computed by using an electronic balance and expressed in kg ha^{-1}. The dried plant samples were powdered finely by using a wiley mill, and the processed samples were used for analyzing the nitrogen, phosphorus, and potassium content. The nitrogen content of the processed samples was estimated using the Micro Kjeldahl method, as suggested by Humphries (1956). The total nitrogen uptake was assessed by multiplying the nitrogen content of the samples with their respective dry matter production and expressed in kg ha^{-1}. For, determining the phosphorus content, triple acid digestion method (vanado molybdate - triacid extract) was adopted as suggested by Jackson (1973). The intensity of color was measured using a spectrophotometer at a wavelength of 470 nm. By referring to the standard curve, the phosphorus uptake was estimated by multiplying the phosphorus content of the sample with the dry matter content and denoted in kg ha^{-1}. The potassium content of the samples was computed using the triple acid digestion method with a flame photometer (Jackson, 1973). The potassium uptake of the samples was calculated by multiplying the estimated potassium content with the total dry matter accumulation and expressed in kg ha^{-1}. All these parameters were estimated at three stages *viz*., flower initiation, pod setting, and harvest stage. The post-harvest availability of soil nitrogen, phosphorus, and potassium was assessed by following the procedures suggested by Subbiah and Asija (1956), Olsen *et al*. (1954), and Stanford and English (1949), respectively. All the data recorded were statistically analyzed using AGRESS software as per the procedure suggested by Gomez and Gomez (2010). For significant treatments, the critical difference was worked out at 5% probability level, and the treatments that were non-significant at 5% probability level were denoted as NS.

RESULTS AND DISCUSSION

Dry matter production

Basal application of diverse levels of nitrogen and foliar nutrition of nano and conventional urea at different concentrations significantly influenced the dry matter production (DMP) of greengram (Table 1).

The maximum DMP (873, 2792, and 4180 kg ha^{-1} at FI, PS, and harvest stage, respectively) was recorded with the application of a higher dose of basal nitrogen (N_1 - 100% RDN), which was significantly higher than 60% RDN and absolute nitrogen control. However, it was on par with 80% RDN (N_2) producing dry matter content of 870 kg ha^{-1} at FI, 2762 kg ha^{-1} at PS and 4097 kg ha^{-1} at harvest stage. The addition of optimum levels of basal nitrogen helped in the synthesis of various growth-promoting enzymes and proteins, which are essential for the plant's metabolic activities, thus considerably maximizing the plant growth and dry matter accumulation. The outcome of the study was in conformity with the research outcomes of Teema *et al*. (2020).

Regarding the foliar feeding practices, significant results were noticed only at the PS and harvest stage, as foliar application was carried out during the time of flower initiation. Foliar fertilization of nano urea @ 4 mL $litre^{-1}$ of water at FI stage and 15 days thereafter (F_3) considerably enhanced the dry matter production, accounting for 2678 kg ha^{-1} at PS stage and 3985 kg ha^{-1} at the harvest stage which was 23.9% and 30.6% higher than foliar nutrition of 1% conventional urea (N_4) which recorded 2162 and 3051 kg ha^{-1} of DMP at PS and harvest stage respectively. Nevertheless, it was statistically on par with foliar feeding of nano urea @ 3 mL $litre^{-1}$ of water at FI stage and 15 days thereafter (F_2). This significant improvement in biomass accumulation was attributable to the foliar feeding of nano urea at FI stage and 15 days thereafter. The larger surface

Table 1. Influence of various dose of basal nitrogen and different concentration of nano urea foliar spray on dry matter production (kg ha^{-1}) of greengram

Treatments	At flower initiation stage (kg ha^{-1})					At pod setting stage (kg ha^{-1})					At harvest stage (kg ha^{-1})				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
N_1	877	860	863	893	873	2783	2960	3034	2390	2792	4137	4510	4637	3436	4180
N_2	860	887	867	867	870	2720	2950	3030	2347	2762	3943	4493	4623	3327	4097
N_3	820	857	866	817	840	2480	2703	2743	2107	2508	3583	3903	4013	2976	3619
N_4	780	783	787	790	785	1827	1883	1903	1803	1854	2550	2627	2666	2463	2577
Mean	834	847	846	842		2453	2624	2678	2162		3553	3883	3985	3051	

Treatments	N	F	N X F	N	F	N X F	N	F	N X F
SEd	24	24	48	87	87	174	108	108	217
CD (P=0.05)	49	NS	NS	177	177	NS	221	221	442

Basal nitrogen dose

N_1 - 100% RDN (25 kg N ha^{-1})
N_2 - 80% RDN (20 kg N ha^{-1})
N_3 - 60% RDN (15 kg N ha^{-1})
N_4 - Control

Foliar spray of nitrogen nutrition

F_1 - Nano urea @ 2 mL litre^{-1} of water at flower initiation stage and 15 days thereafter
F_2 - Nano urea @ 3 mL litre^{-1} of water at flower initiation stage and 15 days thereafter
F_3 - Nano urea @ 4 mL litre^{-1} of water at flower initiation stage and 15 days thereafter
F_4 - 1% urea (Normal) at flower initiation stage and 15 days thereafter

area possessed by the nanoparticles and also their smart nutrient delivery pattern led to the effective absorption and efficient utilization of nutrients applied on the foliage of crops, thus resulting in enhanced dry matter production. Preetha and Balakrishnan (2017) also discoursed the significance of nano synthesized fertilizers for enhancing the growth and development of crops.

Interaction effect of the treatment factors N and F were non-significant during the FI and PS stage, however significant difference was observed at the harvest stage. On comparing all the treatment combinations, combined application of 100% RDN and foliar spray of nano urea @ 4 mL litre^{-1} of water at FI stage and 15 days thereafter (N_1F_3) significantly improved the DMP (4637 kg ha^{-1} at harvest stage) which was closely followed by basal application of 80% RDN + foliar nutrition of nano urea @ 3 mL litre^{-1} of water at FI stage and 15 days thereafter (N_2F_3 - 4623 kg ha^{-1}). On contrary, the minimum DMP (2463 kg ha^{-1}) was registered in nitrogen free control plots supplemented with 1% conventional urea spray (N_4F_4). Basal application of 100% and 80% RDN boosts up the growth of the crop starting from the seedling stage up to the grand vegetative phase. Further, application of nano urea as foliar nutrition satisfies the crop's nutrient requirement at later stages thus resulting in improved dry matter accumulation. Thus, the combined approach of nutrient management significantly augments the dry matter production of summer irrigated greengram. These results were in association with the research findings of Ajithkumar *et al*. (2021) and Sharma *et al*. (2022) in maize and pearl millet respectively.

Nutrient acquisition (Nitrogen, phosphorus and potassium)

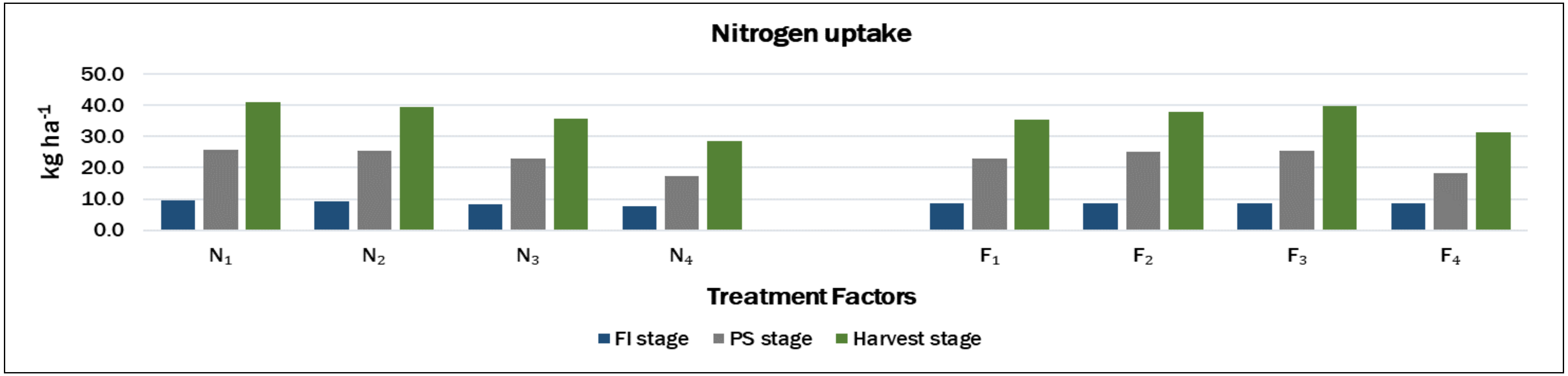
Acquisition of primary nutrients *viz*., nitrogen, phosphorus, and potassium, were significantly influenced by both the treatment factors under investigation (Figure 1, 2 and 3).

With regard to basal application of diverse levels of nitrogen (N), the highest uptake of nutrients *viz*., nitrogen (9.6, 25.9 and 41.0 kg N ha^{-1} at FI, PS and harvest stage respectively), phosphorus (1.32, 5.30, 7.55 kg P_2O_5 ha^{-1} at FI, PS and harvest stage respectively) and potassium (9.7, 38.3, 64.0 kg K_2O ha^{-1} at FI, PS and harvest stage respectively) were recorded under 100% RDN (N_1) which was followed by 80% RDN (N_2). While, the lowest uptake of nutrients was observed under the absolute nitrogen free control plots (N_4) accounting to 7.7, 17.2 and 28.6 kg of N ha^{-1}, 0.93, 3.73, 5.22 kg of P_2O_5 ha^{-1} and 8.3, 25.1, 45.1 kg of K_2O ha^{-1} at FI, PS and harvest stage respectively. This enhancement in uptake of nutrients in application of 100% RDN was attributed to the maximum growth and development of greengram starting from the seedling stage till the harvest stage with accumulation of more biomass plant^{-1}. Nitrogen is the key element of amino acids and is also linked with the process of photosynthesis. So, the plants supplied with an adequate amount of nitrogen experiences vigorous growth with enhanced photosynthetic rates. The findings of the current study were in accordance with the earlier findings of Ghule *et al.* (2020).

Among the various foliar feeding practices, foliar fertilization of nano urea @ 4 mL litre^{-1} of water at FI stage and 15 days thereafter (F_3) markedly improved the uptake of nitrogen (25.5 and 39.8 kg ha^{-1} at PS and harvest stage respectively), phosphorus (5.17 and 7.45 kg ha^{-1} at PS and harvest stage respectively) and potassium (37.1 and 62.9 kg ha^{-1} at PS and harvest stage respectively) which was comparable with nano urea foliar spray @ 3 mL litre^{-1} of water at FI stage and 15 days thereafter (F_2). Whereas, the minimum uptake of nutrients was registered with foliar feeding of 1% conventional urea (F_4), accounting for 18.2 and 31.5 kg of N ha^{-1}, 4.06 and 5.69 kg of P_2O_5 ha^{-1}, 28.2 and 48.7 kg of K_2O ha^{-1} at PS and harvest stage respectively. This substantial improvement in the uptake of primary nutrients by the plants supplemented with nano urea liquid fertilizer was due to the innovative and controlled release mechanism exhibited by nanotechnology-based nitrogen formulation, which gets effectively absorbed by the plants, thus substantially increasing the acquisition of nutrients, thereby augmenting their use efficiency. These results were in corroboration with the results of Sharma *et al*. (2022).

Considering the effect of interaction between the treatment factors investigated, it was statistically observed that the maximum uptake of nutrients *viz*., nitrogen (28.5 and 44.2 kg ha^{-1} at PS and harvest stage respectively), phosphorus (5.71 and 8.56 kg ha^{-1} at PS and harvest stage respectively) and potassium (41.3 and 70.3 kg ha^{-1} at PS and harvest stage respectively) was observed in the treatment combination of 100% RDN and foliar nutrition of nano urea @ 4 mL litre^{-1} of water at FI stage and 15 days thereafter (N_1F_3)

Figure 1. Effect of varied levels of basal nitrogen and diverse concentration of nano urea foliar spray on nitrogen uptake (kg ha^{-1}) by greengram



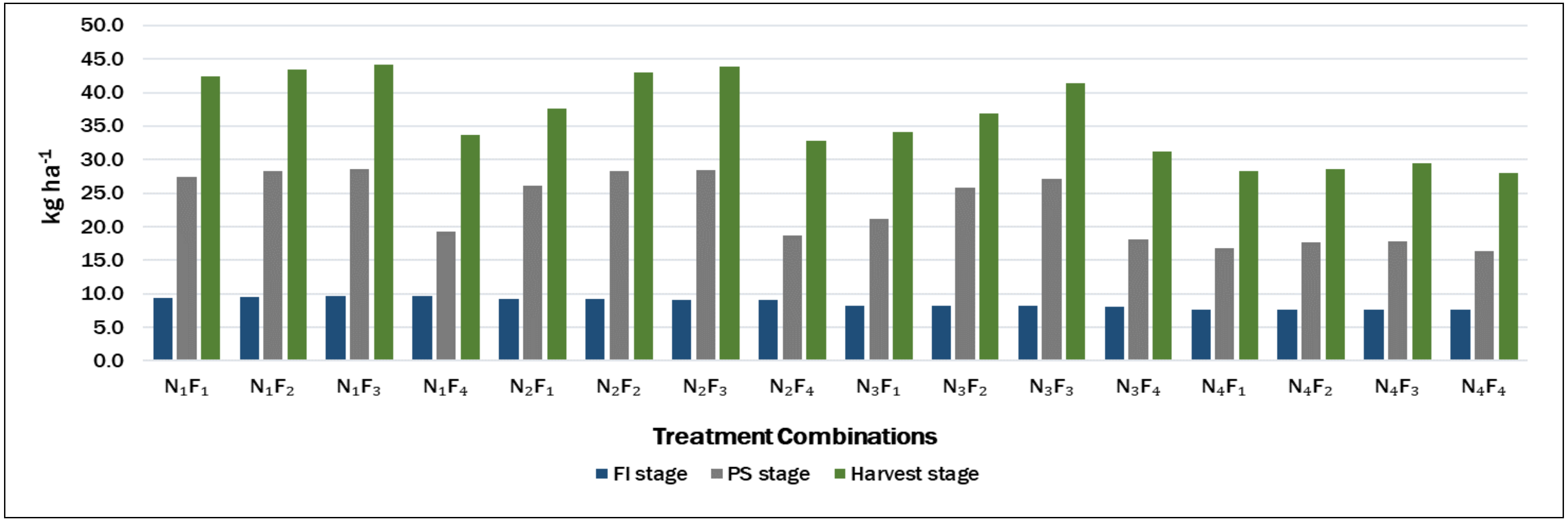
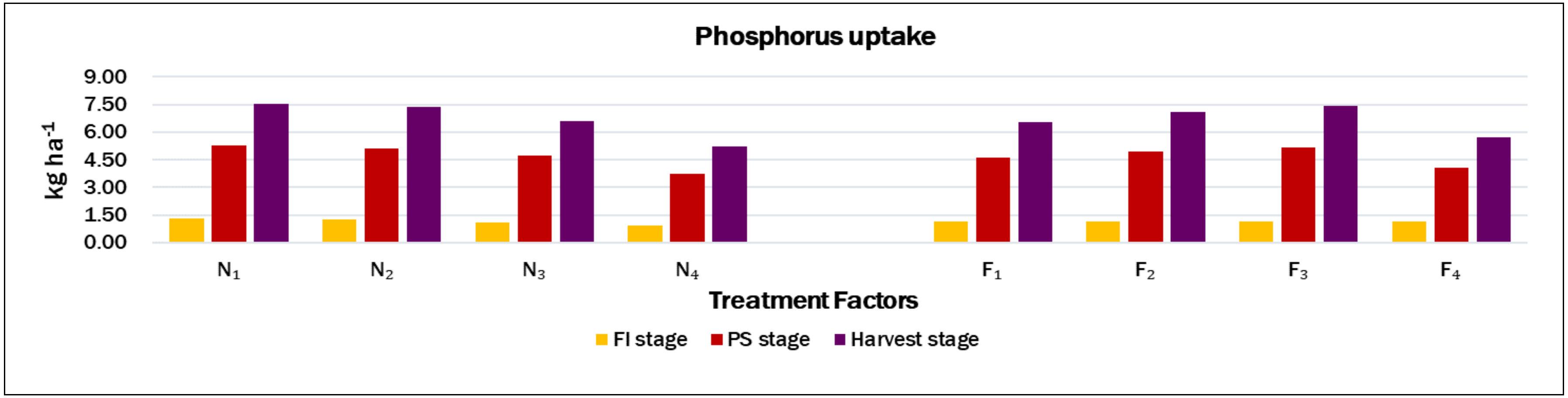


Figure 2. Influence of different dose of basal nitrogen and various concentration of nano urea foliar spray on phosphorus uptake (kg ha^{-1}) by greengram



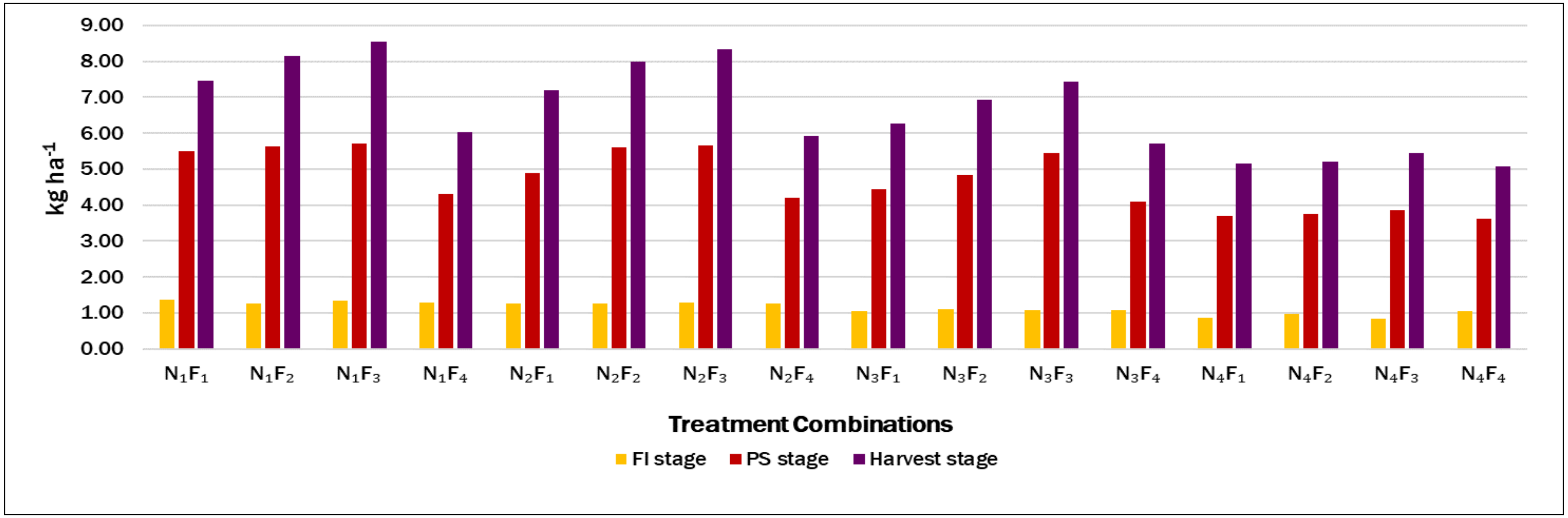
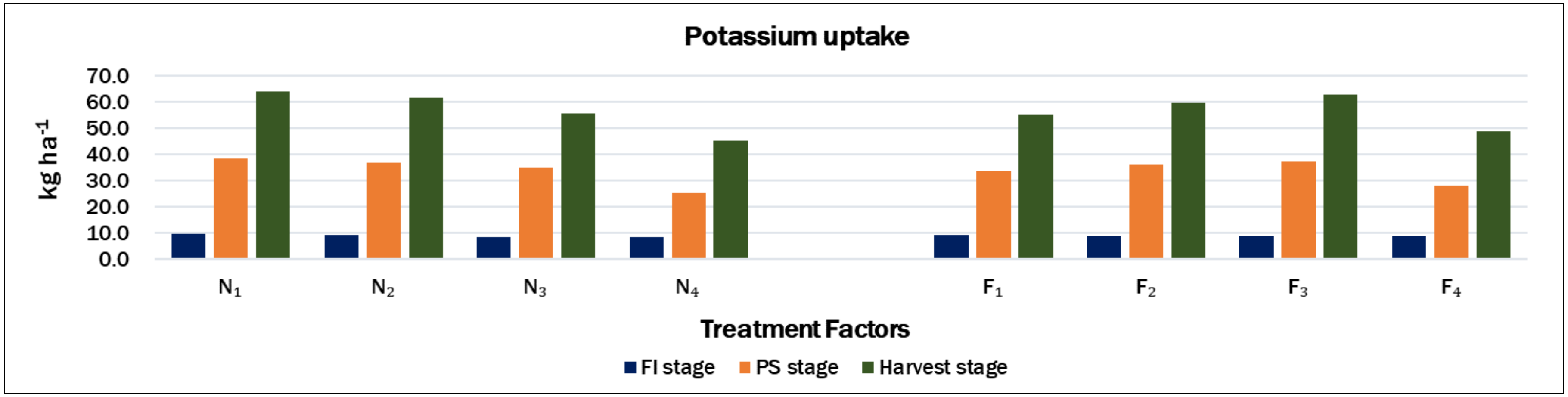


Figure 3. Effect of diverse levels of basal nitrogen and varied concentration of nano urea foliar spray on potassium uptake (kg ha^{-1}) by greengram



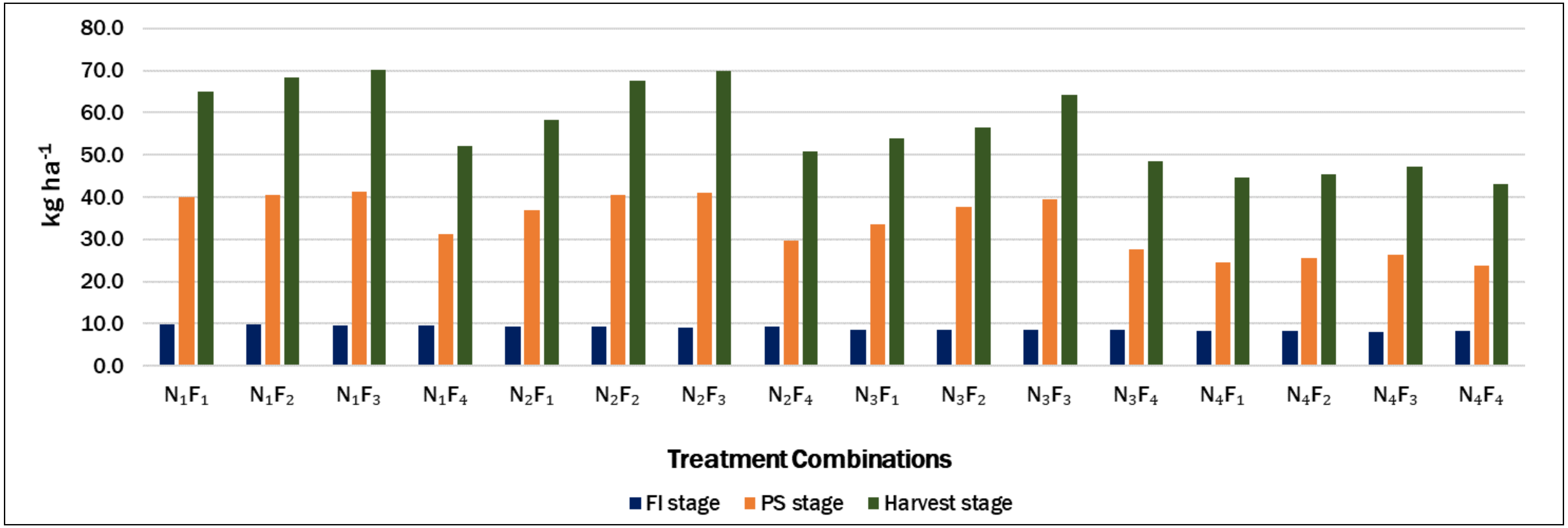


Table 2. Effect of diverse levels of basal nitrogen and various concentration of nano urea foliar spray on post-harvest soil nutrients (N, P and K - kg ha-1)

Treatments	Nitrogen (kg ha-1)					Phosphorus (kg ha-1)					Potassium (kg ha-1)				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
N_1	194.9	192.9	193.1	201.1	195.5	20.9	21.6	18.3	22.4	20.8	802.3	805.6	800.2	818.1	806.6
N_2	195.2	190.0	190.4	195.6	192.8	22.2	19.0	22.8	21.2	21.3	815.3	812.3	808.2	822.4	814.6
N_3	194.7	192.1	188.4	196.6	193.0	20.4	23.6	22.6	22.5	22.3	817.1	816.4	807.3	832.9	818.4
N_4	191.2	189.7	190.9	193.5	191.3	22.6	21.4	22.1	23.2	22.3	826.5	824.1	833.2	839.4	830.8
Mean	194.0	191.2	190.7	196.7		21.5	21.4	21.5	22.3		815.3	814.6	812.2	828.2	

Treatments	N	F	N X F	N	F	N X F	N	F	N X F
SEd	6.8	6.8	13.5	0.8	0.8	1.6	28.6	28.6	57.2
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Basal nitrogen dose

N_1 - 100% RDN (25 kg N ha^{-1})
N_2 - 80% RDN (20 kg N ha^{-1})
N_3 - 60% RDN (15 kg N ha^{-1})
N_4 - Control

Foliar spray of nitrogen nutrition

F_1 - Nano urea @ 2 mL $litre^{-1}$ of water at flower initiation stage and 15 days thereafter
F_2 - Nano urea @ 3 mL $litre^{-1}$ of water at flower initiation stage and 15 days thereafter
F_3 - Nano urea @ 4 mL $litre^{-1}$ of water at flower initiation stage and 15 days thereafter
F_4 - 1% urea (Normal) at flower initiation stage and 15 days thereafter

which was followed by integrated application of 80% RDN + foliar feeding of nano urea @ 4 mL litre^{-1} of water at FI stage and 15 days thereafter (N_2F_3). On the other hand, the uptake of nutrients was minimum in nitrogen free control plots supplemented with 1% conventional urea spray (N_4F_4) recording the values of 16.4 and 28.0 kg of N ha^{-1}, 3.62 and 5.08 kg of P_2O_5 ha^{-1}, 23.9 and 43.1 kg of K_2O ha^{-1} at PS and harvest stage respectively. Application of 100% and 80% RDN supplied optimal quantity of nitrogen required for the crop to nourish and develop to its maximum potential. Likewise, foliar fertilization of nano urea at FI stage and 15 days thereafter further promoted the growth and development of crops producing more biomass yield by better uptake of available nutrients from soil as well as the foliage. Thus, the cumulative effect of both soil and foliar applied nutrition facilitated the higher uptake of primary nutrients by greengram. Similar research findings were also reported in rice (Chandana *et al*., 2021) and potato (Neogi and Das, 2022).

Post-harvest soil available nutrients

Post-harvest soil available nutrients were not significantly influenced by the treatment factors but there existed a trivial numerical variation (Table 2).

Basal application of 100% RDN (N_1) recorded the highest post-harvest availability of soil nitrogen (195.5 kg ha^{-1}) followed by 60% RDN (N_3). While, the lowest post-harvest availability of soil nitrogen (191.3 kg ha^{-1}) was noticed in nitrogen free control plots (N_4). On the contrary, post-harvest availability of soil phosphorus (22.3 kg ha^{-1}) and potassium (830.8 kg ha^{-1}) were maximum in absolute nitrogen free control plots (N_4) followed by 60% RDN (N_3) and the least availability of post-harvest soil phosphorus (20.8 kg ha^{-1}) and potassium (806.6 kg ha^{-1}) was observed in 100% RDN (N_1).

With regard to foliar fertilization practices, 1% conventional urea spray (F_4) recorded higher availability of nitrogen (196.7 kg ha^{-1}), phosphorus (22.3 kg ha^{-1}), and potassium (828.2 kg ha^{-1}) followed by foliar application of nano urea @ 2 mL litre^{-1} of water at FI stage and 15 days thereafter (F_1). Whereas, the availability of post-harvest soil nutrients was lower in the foliar nutrition practices of nano urea @ 3 mL and 4 mL litre^{-1} of water at FI stage and 15 days thereafter (F_2 and F_3). The post-harvest availability status of soil nitrogen, phosphorus and potassium were lower in the plots where the dry matter content and nutrient acquisition were maximum. This was due to the fact that crop growth and acquisition of nutrients are positively correlated *i.e.*, for the maximum growth, the crop requires more amount of nutrients. This improved acquisition of nutrients led to a decline in the nutritional status of post-harvest soil in the experimental field.

CONCLUSION

From the experimental results, it was evident that application of 100% and 80% RDN integrated with foliar fertilization of nano urea @ 4 mL litre^{-1} of water at FI stage and 15 days thereafter significantly improved the dry matter production and acquisition of primary nutrients *viz*., nitrogen, phosphorus and potassium by greengram. As, both the treatment combinations produced comparable results, integrated application of 80% RDN as basal dose and foliar nutrition of nano urea @ 4 mL litre^{-1} of water at FI stage and 15 days thereafter would be a feasible approach for enhancing the dry matter accumulation and nutrient uptake of greengram under irrigated conditions.

CONFLICT OF INTEREST

All authors declare that they have no conflict of interest.

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