

EFFECT OF PLANT SPACING AND NUTRIENT MANAGEMENT ON BULB YIELD OF RATOON ONION

S. BRAHMA¹, M. N. YOUSUF^{2*}, M. A. A. KHAN³
M. I. HAQUE⁴ AND R. ARA⁵

Abstract

A field experiment was conducted at Regional Spices Research Centre, BARI, Gazipur during two growing seasons of 2020-2021 and 2021-2022. The objective of the study was to find out the suitable plant spacing and develop a nutrient management package for maximizing the yield of ratoon onion. The experiment was conducted in a Factorial Randomized Complete Block Design having three replications. There were 9 treatments comprising three levels of plant spacing: 10 cm X 10 cm, 15 cm X 10 cm and 20 cm X 10 cm with three nutrient management packages: Soil test basis ($N_{90}P_{37}K_{80}S_{15}Zn_{1.5}B_1$ kg ha⁻¹) with cowdung 3 t ha⁻¹, RDF ($N_{110}P_{45}K_{120}S_{30}Zn_3B_{1.5}$ kg ha⁻¹) with cowdung 5 t ha⁻¹ and farmer's practices ($N_{120}P_{50}K_{85}S_{20}$ kg ha⁻¹). Results revealed significant effect for plant spacing and nutrient management as well as their interaction on the yield components and bulb yield of ratoon onion. The highest bulb yield (12.1 and 14.33 t ha⁻¹ in 2020-2021 and 2021-2022, respectively), was obtained with plant spacing (10 cm x 10 cm) along with the RDF ($N_{110}P_{45}K_{120}S_{30}Zn_3B_{1.5}$ kg ha⁻¹) with cowdung 5 t ha⁻¹. The cost benefit analyses also showed the maximum net income (594857 taka) from the same treatment combination. Therefore, the same treatment package (10 cm x 10 cm spacing and $N_{110}P_{45}K_{120}S_{30}Zn_3B_{1.5}$ kg ha⁻¹ with cowdung 5 t ha⁻¹) may be recommended for maximizing the bulb yield of ratoon onion in Grey Terrace Soil of Madhupur Tract (AEZ-28) at Gazipur and under similar agro-climatic condition elsewhere in the country.

Keywords: Ratoon onion or *murikata piaz*, plant spacing, nutrient management and bulb yield

Introduction

Onion (*Allium cepa* L.) belongs to the family Alliaceae, originated in Central Asia, is an important cash crop cultivated throughout the world. Its bulbs, some cases leaves and inflorescences are used as spices or vegetables for its medicinal, nutritional and seasoning properties (Yousuf *et al.*, 2022). The annual production of onion bulbs is about 22.69 lakh Metric tons, covering 1.94 lakh hectares of land in Bangladesh (BBS, 2022), which is insufficient from the annual total demand. There are many obstacles behind increasing bulb production of onion such as lack of improved and hybrid varieties, inadequate supply of quality seeds, environmental vulnerability, suitable land availability, limitation of agricultural

^{1,2&4}Senior Scientific Officer, ³Scientific Officer, and ⁵Principal Scientific Officer, Regional Spices Research Centre, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh.

policy and unstable marketing facilities. Decreasing cultivable lands restricts horizontal expansion of onion production, Therefore, inclusion of summer onion and also ratoon onion production are getting practical significance. The cultivation of onion, locally known as *murikata piaz*, could be one of the ways to solve onion crisis during period of September to January. For ratoon onion, at first bulblets are produced in *rabi* season, then these bulblets in next late *kharif* and early *rabi* season. Bulblets to bulb production of onion are influenced by several factors: bulblets size, planting time, plant spacing, climatic vulnerability, weed-insect-disease pest infestation, plant nutrients, water management and cultural management etc. (Alemu *et al.*, 2022; Yousuf *et al.*, 2022). Among these, plant spacing and nutrient management play very important role in bulblets to bulb production of onion (Wassie *et al.*, 2022). Optimum plant spacing avoids competition between plants for sunlight, water, nutrients, lands and ensures optimum bulb size, shape, weight and yield (Gebretsadik and Dechassa, 2018). Closer spacing accommodates higher plant populations resulted in higher total bulb yield with smaller bulb size, shape and lower shelf-life in storage than wider spacing (Islam *et al.*, 2019; Walle *et al.*, 2018). Nutrient management is essential for optimum crop yield and conserving environment when application in balanced ways with right time and right method (Khokhar, 2019). Combination of chemical fertilizers with organic manures had positive influence on vegetative growth (Plant height, Number of leaves per plant, neck thickness, dry matter), reproductive growth (bulb size, weight and yield) and qualitative parameters (TSS, bulb shape, color, shelf life and chemical composition) of onion (Mekonnen *et al.*, 2017; Fekry, 2017). Application of deficient amounts of nutrient elements results small sized and early mature bulb on the other hands excess levels, cause large necks, doubles, soft bulbs with poor shelf-life (Hamasaki *et al.*, 1999). Many other researchers also reported that suitable plant spacing and judicious application of plant nutrients can produce optimum plant growth, yield, quality and storability of onion (Fekry, 2017; Gebrekorkos *et al.*, 2017). Production of ratoon onion from bulblets is a highly specialized task; maintaining optimum plant density and nutrient management. To rationalize the above-mentioned situation this study was undertaken: to identify the best suited plant spacing for onion from bulblets to bulb production and to develop a standard nutrient management package for maximization of the yield.

Materials and Methods

The present study was conducted at the research field of Regional Spices Research Center, BARI, Gazipur, during two consecutive growing seasons of 2020-2021 and 2021-2022. The experimental site was situated at 23⁰59' North Latitude and 90⁰24' East Longitude, at an altitude of 8.4 m above the mean sea level. The soil of the experimental site belongs to Chhiata Soil series and has been classified as Grey Terrace Soil, which falls under Inceptisol in Taxonomy under the AEZ-28 (Madhupur Tract) reported by Brammer, 1971. The initial soil samples of the

experimental field were collected (0-15 cm depth) and analyzed in the Soil Science Laboratory, BARI, Gazipur following standard and recommended methods both the years (Table 1). The trial was laid out in a factorial Randomized Complete Block Design with three replications. There were 9 treatment combinations formulated with 3 levels of spacing such as S₁: 10 cm X 10 cm, S₂: 15 cm X 10 cm and S₃: 20 cm X 10 cm (accommodating 10,00,000, 6,70,000 & 5,00,000 plant populations per hectare, respectively) with 3 nutrient management packages viz., NM₁: Soil test basis (N₉₀P₃₇K₈₀S₁₅Zn_{1.5}B₁kg ha⁻¹) plus cowdung 3 t ha⁻¹, NM₂: RDF(N₁₁₀P₄₅K₁₂₀S₃₀Zn₃B_{1.5} kg ha⁻¹) plus with cowdung 5 t ha⁻¹ and NM₃: Farmer's dose (N₁₂₀P₅₀K₈₅S₂₀ kg ha⁻¹). The cowdung contained 0.99% N, 0.19% P, 0.49% K, 0.11% S, 0.39% Ca and 0.20% Mg on dry weight basis. The test crop was onion cv. BARI Piaz-4, which was released by BARI in 2008 for *rabi* season. The bulb is a single (non-splitted), flat-round shape, shining red color, pungent medium sized and short duration high yielding variety, grown all over the country. Before planting, the bulblets (10±2 g sized) of onion were treated with Autostin (*Carbendazim*) @ 2 g kg⁻¹ to control primary seed-borne diseases. After that the bulblets were dried in a shade, the planted-on 10 October 2021 and 13 October 2022 in the experimental plot. The unit plot size was 3.0 m x 1.2 m with 30 cm deck around the plot. Cowdung, P, K, S, Zn and B were applied to soil as basal before final land preparation. Nitrogen from urea was applied at two equal splits at 25 and 60 days after planting. The intercultural operations like three hand weeding, spraying of Ridomil Gold (*Mancozeb + Metalaxyl*) @ 2.5 g l⁻¹ for disease management and Imitaf (*Imidacloprid*) @ 2.0 ml l⁻¹ for insect pests management at 12 days interval. The mature bulbs were harvested on 20 December both in the years. Data on plant height, number of leaves per plant, bulb size and individual bulb weight were recorded for each treatment from randomly selected 10 plants. Total yield of bulbs per plot was converted to yield per hectare. The recorded data on different parameters were statistically analyzed by using *R* version 3.5.0 software to find out the significant variation resulting from different treatments. The difference between treatment means were judged by Least Significant Difference (LSD) test at 5% level of significance.

Table 1. Physical and chemical properties of initial soil at the experimental field during 2020-2021 and 2021-2022

Soil characteristics	Analytical value		Analytical method
	2020-2021	2021-2022	
Soil Textual class	Silty clay loam	Silty clay loam	Hydrometer method
Bulk density (g cm ⁻³)	1.39	1.38	Core sampling method
Particle density (g cm ⁻³)	2.61	2.63	Pycnometer method
Soil pH	5.93	5.84	Soil: water=1:2.5
Total N (%)	0.09	0.09	Modified Kjeldhal Method
Organic C (%)	0.9	0.86	Wet oxidation method

Soil characteristics	Analytical value		Analytical method
	2020-2021	2021-2022	
Available P (ppm)	7.01	6.80	Bray and Kurtz method
Exchangeable K (meq100g ⁻¹ soil)	0.07	0.06	N NH ₄ OAc extraction method
CEC (meq 100g ⁻¹ soil)	9.35	9.05	N NH ₄ OAc extraction method
Available B (ppm)	0.12	0.12	Calcium chloride extraction method
Available Zn (ppm)	0.38	0.41	DTPA Extraction method
Available Cu (ppm)	0.2	0.15	DTPA Extraction method
Available Mn (ppm)	0.66	0.68	DTPA Extraction method
Available S (ppm)	7.0	6.9	Calcium dihydrogen phosphate extraction method

Average monthly weather parameters

During the experimental periods, the monthly average maximum and minimum temperature, monthly average relative humidity and monthly average rainfall data were recorded and presented in Figure 1a, 1b, 2a and 2b.

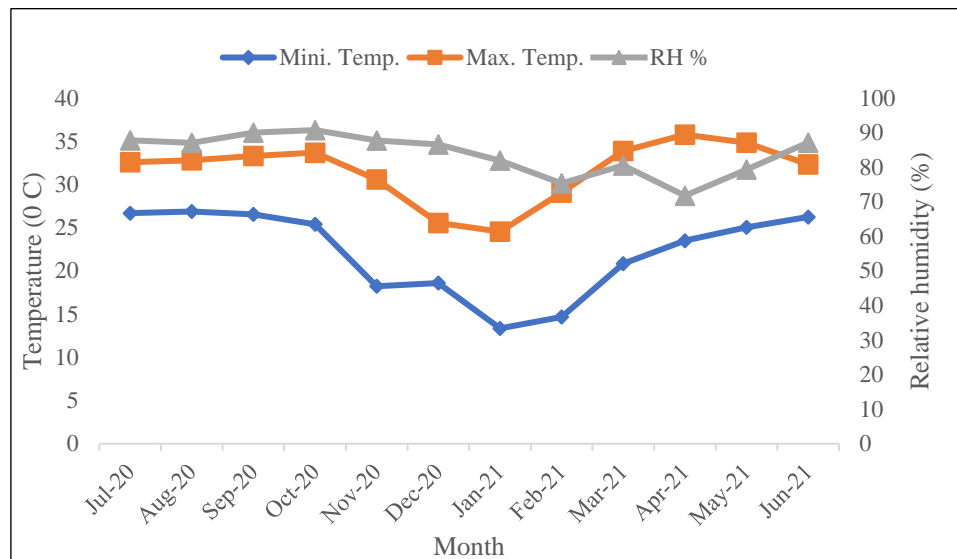


Fig. 1a. Monthly average maximum & minimum temperature with monthly average relative humidity of the BARI experimental farm during July 2020 to June 2021.

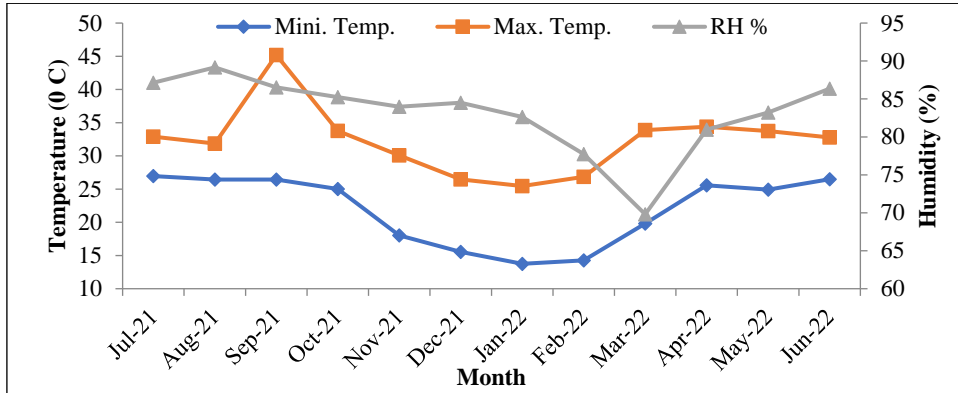


Fig. 1b. Monthly average maximum & minimum temperature with monthly average relative humidity of the BARI experimental farm during July 2021 to June 2022.

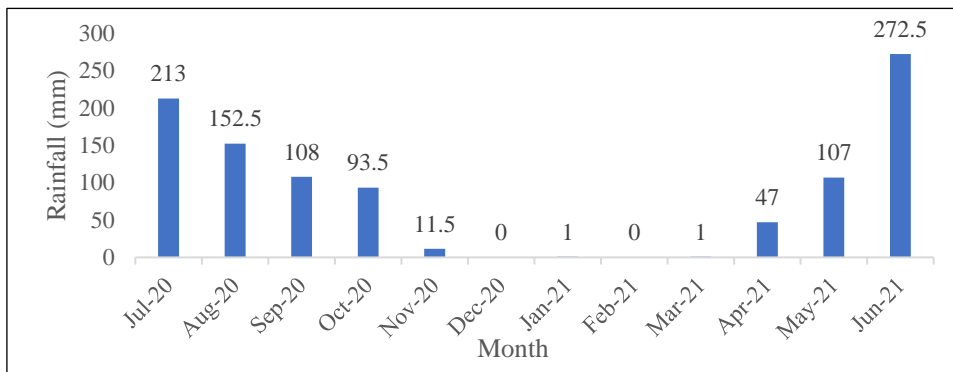


Fig.2a. Monthly average rainfall of the BARI experimental farm during July 2020 to June 2021.

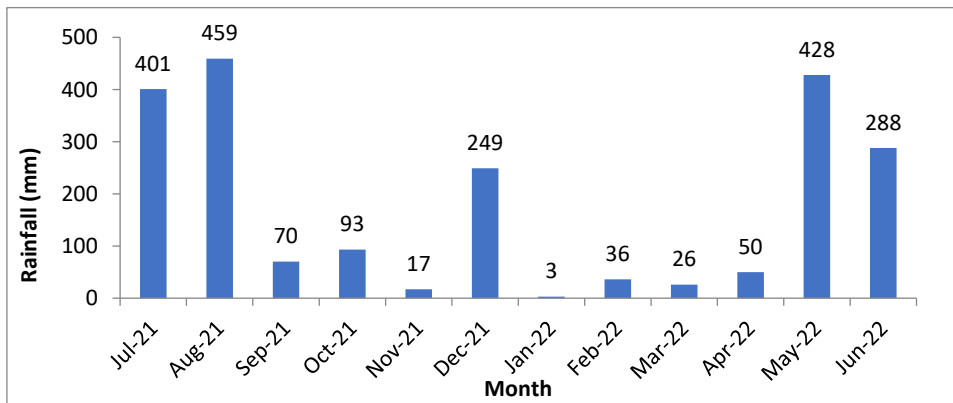


Fig. 2b. Monthly average rainfall of the BARI experimental farm during July 2021 to June 2022.

Results and Discussion

Plant height

The highest plants height (55.7 cm) was recorded from $S_3 \times NM_2$ (plant spacing: 20 cm X 10 cm with application of RDF: $N_{110}P_{45}K_{120}S_{30}Zn_3B_{1.5}$ kg ha⁻¹ plus cowdung at 5 t ha⁻¹), which was significantly higher over rest of the combinations in 2020-2021. In case of the second year (2021-2022), the same treatment attained the maximum plant height (41.8 cm) was statistically similar to $S_1 \times NM_1$ and $S_3 \times NM_3$ but significantly higher over rest of the treatments (Table 2). The lowest plant height (26.3 and 29.7 cm in 2020-2021 and 2021-2022, respectively) was recorded from $S_1 \times NM_3$ (plant spacing: 10 cm X 10 cm and with farmers' dose: $N_{120}P_{50}K_{85}S_{20}$ kg ha⁻¹). The optimum plant spacing and fertilizer dose might have contributed to elongate the plant height. The results are in agreement with the findings of Khan *et al.* (2021) and Ahmed *et al.* (2021).

Number of leaves per plant

The combined effects of plant spacing and nutrient management on the was also on the variation of statistically number of leaves per plant was also found significant (Table 2). The maximum number of leaves per plant (13.0 and 15.7 in 2020-2021 and 2021-2022, respectively) was observed in $S_3 \times NM_2$ treatment which was statistically identical to $S_2 \times NM_2$ but significantly higher over rest of the treatments. Although similar trend was observed in the second year too, but the same treatment ($S_3 \times NM_2$) was significantly higher only over $S_2 \times NM_3$. The minimum number of leaves per plant (6.7 and 10.3 in 2020-2021 and 2021-2022, respectively) were recorded in $S_1 \times NM_3$ (plant spacing: 10 cm X 10 cm with farmer's dose). The results are in agreement with the findings of Mazumder *et al.* (2019) and Gebretsadik and Dechassa (2018).

Bulb size

The treatment combination ($S_3 \times NM_2$) gave the maximum bulb length (4.4 cm and 4.8 cm in 2020-2021 and 2021-2022, respectively), which was significantly higher over $S_1 \times NM_3$, $S_2 \times NM_3$ and $S_3 \times NM_3$ but statistically similar to rest of treatments in the first year. The maximum bulb diameter (3.4 cm and 4.1 cm in 2020-2021 and 2021-2022, respectively) was recorded from $S_3 \times NM_2$ combination closely flowed by $S_2 \times NM_2$ and $S_1 \times NM_2$ in both years, $S_1 \times NM_1$ and $S_3 \times NM_1$ in first year. Wider spacing revealed optimum sunlight, nutrient availability and sufficient moisture gave bigger sized bulb of onion. Almost similar trend or result was noted in the second year (Table 2). Gebrekorkos *et al.* (2017) and Khan *et al.* (2021) reported that optimum plant spacing and judicious nutrient management enhance bulb size.

Table 2. Combined effects of plant spacing and nutrient management on the vegetative growth components of onion

Plant spacing X Nutrient management	Plant height (cm)		No. of leaves per plant		Bulb size			
	2020- 21	2021- 22	2020- 21	2021- 22	Bulb length (cm)		Bulb diameter (cm)	
					2020-21	2021- 22	2020-21	2021- 22
S ₁ X NM ₁	42.3cd	37.5ab	8.3de	12.3ab	4.0ab	2.7d	2.9abc	2.9bc
S ₁ X NM ₂	34.0e	35.3bcd	9.7cd	12.7ab	4.4a	3.7bc	3.2ab	3.5ab
S ₁ X NM ₃	26.3f	29.7d	6.7f	10.3b	3.6bc	3.1cd	2.7c	3.3bc
S ₂ X NM ₁	50.0b	34.0bcd	9.7cd	12.0ab	3.9abc	3.3cd	2.8bc	3.1bc
S ₂ X NM ₂	44.3c	35.7bc	12.0ab	13.7ab	4.1ab	3.9abc	3.2ab	3.4ab
S ₂ X NM ₃	33.3e	30.7cd	8.0ef	11.3b	3.3c	2.7d	2.7c	2.6c
S ₃ X NM ₁	48.7b	33.7bcd	10.7bc	13.7ab	4.2ab	4.6ab	3.1abc	2.9bc
S ₃ X NM ₂	55.7a	41.8a	13.0a	15.7a	4.4a	4.8a	3.4a	4.1a
S ₃ X NM ₃	40.3d	37.0ab	9.0de	13.0ab	3.7bc	4.4ab	2.8bc	2.6c
CV (%)	4.99	9.79	9.6	12.08	8.78	14.17	8.79	12.51

Treatment means followed by the same letter(s) do not differ significantly at 5% level of probability by LSD test

Single bulb weight

Single bulb weight was increased significantly due to interaction effect between plant spacing and nutrient management (Table 3). The highest weight (52.3 and 55.7 g in 2020-2021 and 2021-2022, respectively) of individual bulb was documented in S₃ x NM₂ treatment. The similar single bulb weight was also recorded from S₁ x NM₁, S₂ x NM₁ and S₂ x NM₂ combinations in 2020-2021. The S₃ x NM₂ combination gave significantly the maximum single bulb weight (55.7 g) compared to other combinations in 2021-2022. In case of interaction, nutrient management played major role than plant spacing for increasing the single bulb weight. Similar kind of results were reported by Islam *et al.* (2019); Ferky (2017).

Total bulb yield

The combined effect of plant spacing and nutrient management on bulb yield of ratoon onion was significant (Table 3). The highest bulb yield of onion (12.1 t ha⁻¹ and 14.3 t ha⁻¹ in 2020-2021 and 2021-2022, respectively) was obtained from S₁ x NM₂. The lowest total bulb yield (8.7 t ha⁻¹ and 8.37 t ha⁻¹ in 2020-2021 and 2021-2022, respectively) was recorded from S₃ x NM₃. Closer spacing accommodated higher plant populations and increased total bulb yield and the mean bulb size was proportionately reduced (Walle *et al.*, 2018). Widening

spacing accommodates lower plants significantly increased individual bulb size and bulb production due to lesser competition among them than onion cultivated in closer spacing (Kumar *et al.*, 2018; Gebretsadik and Dechassa, 2018).

Total soluble solids (TSS)

Total soluble solid (TSS ⁰Brix) content in onion bulb was significantly influenced by the combined effects of plant spacing and nutrient management on ratoon onion (Table 3). The treatment combination S₃ x NM₂ gave the highest TSS of onion (12.0 ⁰Brix ¹ in 2020-2021 and 11.0 ⁰Brix ¹ in 2021-2022), which was significantly higher over S₁ x NM₃, S₂ x NM₃ and S₃ x NM₃ but statistically similar to rest of the treatment combinations. This result revealed that nutrient management played major role in increasing the TSS and appeared as the dominant factor in comparison to plant spacing but their suitable combination in better performance of the crop. The results are in agreement with the findings of Walle *et al.*, (2018) and Mekonnen *et al.* (2017).

Table 3. Combined effects of plant spacing and nutrient management on the bulb yield and TSS of onion

Plant spacing x Nutrient management	Single bulb weight (g)		Bulb yield (tha ⁻¹)		TSS(⁰ Brix)	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
S ₁ X NM ₁	41.7c	37.3cd	10.5abc	11.83bc	10.7bc	10.67ab
S ₁ X NM ₂	44.7abc	47.7b	12.1a	14.33a	11.7ab	10.33ab
S ₁ X NM ₃	39.3c	32.7d	11.0ab	9.03de	10.3bc	9.33b
S ₂ X NM ₁	47.7abc	39.7cd	8.9cd	10.84bc	11.0abc	9.33b
S ₂ X NM ₂	51.3ab	48.0b	9.9bcd	12.30b	11.7ab	10.33ab
S ₂ X NM ₃	43.3bc	33.7d	8.7cd	8.50de	10.7bc	9.67ab
S ₃ X NM ₁	45.0bc	44.0bc	8.8cd	10.23cd	11.0abc	11.0a
S ₃ X NM ₂	52.3a	55.7a	9.3bcd	10.93bc	12.0a	11.0a
S ₃ X NM ₃	45.0bc	39.3cd	8.4d	8.37e	10.3c	10.0ab
CV (%)	10.85	9.96	11.53	9.39	5.91	8.24

Treatment means followed by the same letter(s) do not differ significantly at 5% level of probability by LSD

Cost-benefit analysis of Onion

The cost-benefit analysis of onion production using plant spacing and nutrient management (considering the mean bulb yield of both the years) is presented in Table 4 and 5. The benefit of optimum plant spacing and nutrient management practices exceeds farmer`s traditional practice both in yield and return. The highest net benefit (594847 Taka ha⁻¹) was recorded in the treatment combination S₁ x NM₂ and the minimum (368223 Taka) in S₂ x NM₃ (Table 4). Among the treatment

combinations the highest marginal rate of returns (MMR: 87.34%) was recorded in $S_1 \times NM_3$ (Table 5). MRR implies what an investor can get to receive by switching technologies from the traditional practice to the improved new one, hence, (87.34%) MRR indicates that by investing 1 taka a farmer can get benefit 0.87 Taka by using combination $S_1 \times NM_2$ treatment which accommodated 10,00,000 plants.

Table 4. Cost benefit analysis of onion as affected by plant spacing and nutrient management

Plant spacing X Nutrient management	Mean bulb Yield (tha^{-1})	Variable cost (Taka ha^{-1})				Income (Taka ha^{-1})		Rank
		Input cost	Labor cost	Fixed cost	Total variable cost	Gross income	Net income	
$S_1 \times NM_1$	11.2	29342	36000	36250	101592	599200	497608	2
$S_1 \times NM_2$	13.2	36843	38250	36250	111343	706200	594857	1
$S_1 \times NM_3$	10.0	24607	34900	36250	95757	535000	439243	5
$S_2 \times NM_1$	9.9	25715	33750	36250	95715	529650	433935	6
$S_2 \times NM_2$	11.1	33213	36450	36250	105913	593850	487937	3
$S_2 \times NM_3$	8.6	20977	34650	36250	91877	460100	368223	9
$S_3 \times NM_1$	9.5	23845	31500	36250	91595	508250	416655	7
$S_3 \times NM_2$	10.1	31343	32400	36250	99993	540350	440357	4
$S_3 \times NM_3$	8.9	19107	30600	36250	85957	476150	390193	8

Unit price: Urea=16 tk kg^{-1} , TSP=22 tk kg^{-1} , MoP=15 tk kg^{-1} , Gypsum=12.5 tk kg^{-1} , Cowdung= 1.5 tk kg^{-1} , Boric acid= 150 tk kg^{-1} , zinc sulphate=180 tk kg^{-1} , irrigation cost 2250 tk ha^{-1} , land rent=20000 tk ha^{-1} , tractor cost=3200 tk ha^{-1} , bulblets cost=120 and 100 tk kg^{-1} (in 2020-2021 and 2021-2022, respectively), onion sale price=52 and 55 tk kg^{-1} (in 2020-2021 and 2021-2022, respectively), labor=450 tk/day/Person and marketing cost=5000 and 7500 tk ha^{-1} (in 2020-2021 and 2021-2022, respectively)

Table 5. Marginal rate of return (MRR) in onion cultivation as affected by plant spacing and nutrient management

Treatment	Variable cost (TK ha^{-1})	Net income (TK ha^{-1})	MRR (%)	Rank
$S_2 \times NM_3$	91877	368223	-	-
$S_3 \times NM_3$	85957	390193	25.56	4
$S_3 \times NM_1$	91595	416655	28.89	3
$S_2 \times NM_1$	95715	433935	18.05	5
$S_1 \times NM_3$	95757	439243	5.52	7
$S_3 \times NM_2$	99993	440357	1.11	8
$S_2 \times NM_2$	105913	487937	46.83	2
$S_1 \times NM_1$	101592	497608	9.52	6
$S_1 \times NM_2$	111343	594857	87.34	1

Conclusion

Combination of suitable plant spacing and nutrient management augmented yield attributes and bulb yield of ratoon onion with higher economic return as revealed from consecutive two years study conducted in Grey Terrace Soil of Madhupur Tract (AEZ-28) at Joydebpur, Gazipur. The highest bulb yield (12.1 & 14.33 t ha⁻¹ in 2020-2021 and 2021-2022, respectively), and MRR (87.34% in both the years) was recorded from the combination of plant spacing (10 cm x 10 cm, which accommodated 10,00,000 plants) and application of RDF (N₁₁₀P₄₅K₁₂₀S₃₀Zn₃B_{1.5} kg ha⁻¹) with cowdung 5 t ha⁻¹. Plant spacing 10 cm x 10 cm and application of N₁₁₀P₄₅K₁₂₀S₃₀Zn₃B_{1.5} kg ha⁻¹ with cowdung 5 t ha⁻¹ may be suitable for ratoon onion cultivation in Grey Terrace Soil of Madhupur Tract (AEZ-28).

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