Effect of Plant Population on Bulb Size and Yield of Marketable Bulbs of Onion Varieties during Off Season

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ABSTRACT

An experiment was conducted in Sunwal, Nawalparasi district of Nepal to assess the effect of plant population on bulb size and marketable yield of two onion varieties during rainy season of 2008. Two off season varieties of onion as main plot factor viz. Agrifound Dark Red (AFDR) and N-53 and six different plant populations (125, 100, 83.34, 66.67, 50 and 33.34 plants per m^2) obtained by using different spacings of 10×8, 10×10, 12×10,15×10, 20×10 and 20×15 cm as sub plot factors were used as treatments and laid out in a split plot design with three replications. Marketable bulb yield of AFDR (25.55 mt ha^{-1}) was higher than that of N-53 (19.78 mt ha^{-1}). Marketable bulb yield was highest at closer spacing of 10×10 cm for both the varieties which was 26.97 mt ha^{-1} in AFDR and 22.48 mt ha^{-1} in N-53. The size of the bulbs increased with increase in spacing. The most preferred size of bulb was found to be of diameter between 3.5 to 5 cm whose yield was found highest (2.19 kg/plot) at the closest spacing of 10×8 cm which was not statistically different from that (2.17 kg/plot) at the spacing of 10×10 cm. The most preferred sized bulb yield showed a similar trend of increase as total marketable bulb yield with decrease in spacing. The spacings of 12×10, 10×10 and 10×8 cm produced total marketable bulb yields which were not significantly different from each other. The highest net return of Rs. 5,68,977 per hectare was found at the spacing of 12×10 cm for the variety AFDR.

Keywords : Off season, onion, spacing, varieties

INTRODUCTION

Onion (*Allium cepa* L.) is one of the world's most important vegetables and is cultivated in both temperate and tropical regions (Brewester, 1994). It ranks third in production among the vegetable crops in the world after tomato and cabbage (FAO, 1996) while Thapa and Paudyal (2000) reported it to rank 4th in position in terms of its volume and value of the production in Nepal. There is steady demand of onion bulb throughout the year which is increasing every year in Nepal. Severe scarcity of onion bulbs is seen from August to March in the vegetable markets of Nepal which is fulfilled by import from India in the period (Budathoki, 2006) and the condition is aggravated by the storage losses of upto 88% (Srivastava and Sharma, 1994). About 30,781 mt of onions were imported from India during the year 2007/08 (Republica, 2009).

In the context of the steady demand of onion and the import status of the onion bulbs, the production of onion bulbs has been emphasized by the government and the Mission Onion is in action in this line which aims to substitute imports by increasing the land devoted to onion

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farms from 15,062 ha to 27,292 ha across the country by fiscal year 2011/12 (Republica, 2009). This increase in bulb production could further be increased by increasing the productivity of onion bulbs which seems to be very low in Nepal.

Budhathoki *et al.*(2004) reported that Agrifound Dark Red and N-53 are established as promising off season varieties. Currah and Proctor (1990) reported that N-53 and Agrifound Dark Red were suitable for Kharif season (July to November). From the four varieties tested during off season during late rainy season of 2007 under Inner Terai condition, AFDR and N-53 were found to be suitable varieties with higher yields (Dahal, 2008).

Plant population density is one of the important factor that governs bulb size and yield of bulb in onion crop (Brewster, 1990) and the increase in yield is achieved through increased production per unit area. Besides, planting distance can be vital for contributing to better marketable bulb yield in onion (Acharya, 2007).

Thus, there is need of identifying optimum bulb size demanded by the market of a specific locality and appropriate plant population density to achieve maximum yield of bulbs of desired size. Therefore, the present study aims at comparing the two varieties of onion viz., Agrifound Dark Red and N-53 at different population densities so that the effect of plant population on bulb size could be assessed and the appropriate plant population for achieving the higher total yields as well as marketable sized bulb yield could be identified under Terai condition of Nawalparasi district of Nepal.

MATERIALS AND METHODS

The experiment was conducted at Sunawal VDC-1 of Nawalparasi district from July, 2008 to January, 2009. The onion varieties namely N-53 and Agrifound Dark Red (AFDR) were selected for the study. The seedlings were transplanted at the age of 57 days after seed sowing (DAS). Transplanting was done at six different spacings of 10×8 cm, 10×10 cm, 12×10 cm, 15×10 cm, 20×15 cm and 20×15 cm as designated treatments, the gross plot size for the six subplots taking single border row around each subplot according to the spacings were 1.904 m^2, 1.96 m^2, 2.016 m^2, 2.1 m^2, 2.24 m^2 and 2.4 m^2 respectively with 238, 196, 168, 140, 112 and 80 plants respectively and the net plot area contained a plant population of 180, 144, 120, 96, 72 and 48 plants respectively..

The experiment was laid out in split plot design with three replications. There were 12 treatment combinations in a replication consisting of two varieties viz. AFDR and N-53 as the main plot factors and six plant population viz. 125, 100, 83.34, 66.67, 50 and 33.34 plants per m^2 as the subplot factor. The following were the treatment combinations :

Treatment 1 (T1) = 125 plants per m^2 of variety AFDR (10×8 cm)
Treatment 2 (T2) = 100 plants per m^2 of variety AFDR (10×10 cm)
Treatment 3 (T3) = 83.34 plants per m^2 of variety AFDR (12×10 cm)
Treatment 4 (T4) = 66.67 plants per m^2 of variety AFDR (15×10 cm)
Treatment 5 (T5) = 50 plants per m^2 of variety AFDR (20×10 cm)
Treatment 6 (T6) = 33.34 plants per m^2 of variety AFDR (20×15 cm)
Treatment 7 (T7) = 125 plants per m^2 of variety N-53 (10×8 cm)

Treatment 8 (T8) = 100 plants per m^2 of variety N-53 (10×10 cm)
Treatment 9 (T9) = 83.34 plants per m^2 of variety N-53 (12×10 cm)
Treatment 10 (T10) = 66.67 plants per m^2 of variety N-53 (15×10 cm)
Treatment 11 (T11) = 50 plants per m^2 of variety N-53 (20×10 cm)
Treatment 12 (T12) = 33.34 plants per m^2 of variety N-53 (20×15 cm)

A survey was conducted in the district to assess the marketable size of the onion bulbs. For this purpose, four major market areas of the district namely Gaindakot, Kawasoti, Sunwal and Parasi were selected. Five vegetable traders of each market and five onion growing farmers cum traders of the Sunwal and Swanthi VDCs were asked to separate the bulbs on the basis of size in categories like large, medium and small (five in each category) according to their perception. The diameter of five bulbs in each category was measured with the help of a Vernier Calliper. On the basis of the results of the survey as well as support from literature, a grading of the bulbs on the basis of the diameter was done.

The data recorded were entered into the Microsoft Excel spread sheet and were then analyzed by using MSTAT-C for deriving ANOVA. Means were compared by using Duncan's Multiple Range Test (DMRT) at 0.05 level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSIONS

Vegetative characters

The plant height of Agrifound Dark Red (33.40 cm) was significantly higher than the plant height of N-53 (30.69 cm) at 30 days after transplanting (DAT) while the plant height of Agrifound Dark Red and N-53 were not significantly different at 45, 60 and 75 DAT. Spacing and interaction effect of spacing and varieties didn't significantly affect the plant height at 30, 45, 60 and 75 DAT. The number of leaves of variety AFDR was at par with the number of leaves of the variety N-53 at different spacing at 30, 45, 60 and 75 DAT. The interaction effect was also statistically non significant at 45, 60 and 75 DAT while at 30 DAT the interaction effect was found highly significant with the highest number of leaves (5.05) at 20×15 cm and the lowest number of leaves (4.15) in the variety N-53 at the spacing of 10×10 cm.

Quality characteristics

Average polar length of onion bulbs was not significantly different between the varieties. Spacing significantly affected average polar length with the lowest polar length at the spacing of 10×10 cm (i.e., 3.31 cm) which was not significantly different from that of 3.34 cm at the spacing of 10×8 cm. The interaction between varieties and spacings on average polar length was not significant. There was no significant difference between the varieties with respect to the neck thickness and the effect of spacing and interaction effect between varieties and spacings on average neck thickness was also not significant.

AFDR showed the mean bulb diameter of 4.43 cm which was comparatively greater than that of N-53 (4.31 cm) but not different statistically. There was significant difference in the mean diameter of the harvested bulbs due to spacing treatments which also showed similar pattern as the polar length and the neck thickness. The highest mean diameter was 5.09 cm at the widest spacing of 20×15 cm and the lowest (3.91 cm) at the closest spacing of 10×8 cm. The bulb diameter increased with increase in the spacing. Similar results were obtained in case of bulb

diameter in Kharif season in Bangladesh (BARI, 2006 and 2007). With respect to the average mean diameter, the interaction effect between the varieties and spacings was not significant.

With respect to the mean bulb weight, the varieties were significantly different. AFDR with 46.64 g had higher mean bulb weight as compared to N-53 which was 45.03 g (Table 3). Sharma and Neupane (1995) found the average bulb weight to be 32.70 g AFDR which was contradictory to the present reults. While Rokaya *et al.* (2004) reported the bulb weight of 27 to 47 g for the variety Nasik Red-53. There was also significant effect of spacing on the mean bulb weight with lowest mean bulb weight of 34.76 g at the closest spacing of 10×8 cm and the highest mean bulb weight of 61.07 g at the widest spacing of 20×15 cm. The mean bulb weight decreasing with the decrease in the spacing seems in conformity to the findings of the result obtained from experiments in Bangladesh during Kharif season (BARI, 2002, 2006 and 2007). The interaction between varieties and spacings was not significant with respect to the mean bulb weight.

The varieties did not differ significantly in respect of number of single marketable bulbs per plot and percent single marketable bulbs while spacing had significant effect on them while variety and spacing had significant effect on doubled marketable bulbs and percent doubled marketable bulbs with no significant interaction effect.

The number of total marketable and unmarketable bulbs per plot was not significantly different between the two varieties. Spacing had significant effect on marketable bulbs and unmarketable bulbs per plot while the interaction effect was not significant.

Table 1. Number of marketable and unmarketable bulbs per plot of onion varieties at different spacings at Sunwal, Nawalparasi, 2008/09

Treatments	Marketable bulbs per plot	Unmarketable bulbs per plot
Varieties(Main plot)		
Agrifound Dark Red	75.50	12.73
N-53	72.17	10.45
S E_m	1.21	1.03
CD (P=0.05)	NS	NS
Spacing (Sub plot)		
S_1 (10×8 cm)	95.50^a	28.34^a
S_2 (10×10 cm)	95.00^a	21.17^b
S_3 (12×10 cm)	83.00^b	10.34^c
S_4 (15×10 cm)	69.34^c	4.34^d
S_5 (20×10cm)	58.34^d	3.17^d
S_6 (20×15 cm)	41.84^e	2.17^d
Mean	73.83	11.58
S E_m	2.38	1.03
CD (P=0.05)	7.02	3.02
CV%	7.89%	21.65%

Treatments means followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of significance.

Only the varieties differed significantly with respect to TSS content of the bulbs with AFDR showing comparatively higher (10.36 ^{o}Brix) TSS content as compared to N-53 (7.42 ^{o}Brix). Similarly, in case of dry matter percentage, the bulbs of AFDR had significantly higher dry matter percentage (10.98%) as compared to N-53 (10.30%). Spacings and interaction effect were also observed to be non-significant with respect to TSS and dry matter percentage. Shukla and Prabhakar (1989) also reported that there was no effect of spacing on TSS and dry matter percentage of the onion bulbs.

Number and yield of single marketable bulbs in different grades

On the basis of the literature review and survey of the traders and farmers of the district, the bulbs for vegetable or fresh purpose has been classified as given below.

Table 2: Different grades of onion bulbs according to the diameter

Grades	Diameter (cm)	Grade designation
	<2	Unmarketable
Grade I	2-3.5	Small
Grade II	3.5-5	Optimum
Grade III	5-6	Large
Grade IV	>6	Very large

From the market survey, no distinct price variation according to grades or size of bulbs was seen. So, here these grades have only been used to assess the effect of plant population on bulb size.

There was no significant difference in the number of bulbs in grade I and grade II between two varieties and the interaction effect between variety and spacing while spacing had significant effect on them.

Table 3. Number of single marketable bulbs of onion varieties in different grades at different spacings at Sunwal, Nawalparasi, 2008/09

Treatments Varieties(Main plot)	Grade I (2-3.5 cm)	Grade II (3.5-5 cm)	Grade III (5-6 cm)	Grade IV (> 6 cm)
Agrifound Dark Red	17.78	34.73	12.12^{a}	4.39^{a}
N-53	17.62	33.28	9.50^{b}	3.12^{b}
S E_m	0.48	0.75	0.39	0.20
CD (P=0.05)	NS	NS	2.36	1.20
Spacing (Sub plot)				
S_1 (10×8 cm)	32.00^{a}	52.50^{a}	7.17^{c}	0.00^{e}
S_2 (10×10 cm)	28.17^{b}	51.67^{a}	10.17^{b}	0.00^{e}
S_3 (12×10 cm)	20.67^{c}	41.67^{b}	10.84^{b}	2.67^{d}
S_4 (15×10 cm)	12.50^{d}	29.67^{c}	12.34^{ab}	4.34^{c}
S_5 (20×10cm)	8.67^{e}	17.84^{d}	13.84^{a}	6.67^{b}
S_6 (20×15 cm)	4.17^{f}	10.67^{e}	10.50^{b}	8.84^{a}
Mean	17.69	33.99	10.80	3.75
S E_m	0.72	1.84	0.85	0.46
CD (P=0.05)	2.12	5.41	2.51	1.34
CV%	9.93%	13.20%	19.22%	29.48%

The two varieties differed significantly with respect to the number of single marketable bulbs in grade III and grade IV. Similarly, the effect of spacing was significant in these aspects while the interaction effect was found to be non significant.

There was no significant effect of the varieties and interaction with respect to the weight of single marketable bulbs in grade I, II and III while the effect on yield of grade I, II, III and IV bulbs were significant with spacing. AFDR had significantly higher yield of single marketable bulbs in grade II, III and IV than N-53. The interaction effect of varieties and spacings on yield of grade IV bulbs was significant which showed the highest (1.28 kg) weight of bulbs at the widest spacing of 20×15 cm in AFDR and lowest or no bulbs at the spacing of 10×8 and 10×10 cm for both the varieties.

Yield and yield components

The effect of variety and spacing on final plant stand, biological yield and single marketable bulb yield was significant while the interaction effect was not significant. The highest single marketable yield was recorded at the spacing of 10×10 cm to be 3.44 kg which was not significantly different from those at the spacings of 10×8 and 12×10 cm i.e., 3.32 and 3.24 kg per plot respectively. The effect of spacing was only statistically significant in case of doubled marketable bulb yield.

AFDR had the highest total (single + doubled) marketable bulb yield (3.54 kg per plot) which was significantly higher than that of N-53 (2.85 kg). The marketable bulb yield per plot was highest (3.56 kg) at the spacing of 10×10 cm which was not significantly different from 3.42 and 3.41 kg at the spacings of 12×10 cm and 10×8 cm respectively (Table 4). The widest spacing of 20×15 cm produced the lowest (2.69 kg) marketable yield per plot. The interaction effect was not significant. Thus, the average marketable bulb yield per ha was significantly higher in AFDR (24.55 mtha^{-1}) as compared to N-53 which was calculated to be 19.78 mt ha^{-1}. The highest marketable bulb yield per ha (24.72 mt ha^{-1})was recorded at the spacing of 10×10 cm which was not significantly different from 23.73 and 23.66 mt ha^{-1} at the spacings of 12×10 and 10×8 cm respectively. The lowest marketable yield per ha of 18.64 mt ha^{-1} was exhibited by the widest spacing of 20×15 cm.

Significantly maximum bulb productivity and also the marketable bulb productivity at harvest were recorded at 10×10 cm spacing, which decreased linearly with an increase in plant spacing (Shrivastava *et. al.*, 1996). These results are in conformity. Similar results were also reported by Randhawa and Singh (1974), Brewster and Salter (1980) and Khare (1985) who observed that the total economic productivity of onion increased with increased plant density until an optimum was reached and then declined sharply.

Table 4. Single, doubled and total marketable bulb yield of onion varieties at different spacings at Sunwal, Nawalparasi, 2008/09

Treatments Varieties(Main plot)	SMBY (kg /plot)	DMBY (kg/plot)	TMBY (kg/plot)	TMBY (mt ha^{-1})
Agrifound Dark Red	3.32^{a}	0.22	3.54^{a}	24.55^{a}
N-53	2.61^{b}	0.24	2.85^{b}	19.78^{b}
S E_m	0.05	0.01	0.05	0.32
CD (P=0.05)	0.26	NS	0.28	1.90
Spacing (Sub plot)				
S_1 (10×8 cm)	3.32^{a}	0.10^{d}	3.41^{a}	23.66^{a}
S_2 (10×10 cm)	3.44^{a}	0.13^{d}	3.56^{a}	24.72^{a}
S_3 (12×10 cm)	3.24^{a}	0.19^{c}	3.42^{a}	23.73^{a}
S_4 (15×10 cm)	2.87^{b}	0.22^{c}	3.09^{b}	21.42^{b}

S_5 (20×10cm)	2.67[b]	0.34[b]	3.00[b]	20.82[b]
S_6 (20×15 cm)	2.28[c]	0.41[a]	2.69[c]	18.64[c]
Mean	2.96	0.22	3.19	22.17
S E_m	0.11	0.02	0.11	0.73
CD (P=0.05)	0.32	0.06	0.31	2.13
CV%	8.77%	17.41%	7.96%	7.96%

SMBY, Single marketable bulb yield; DMBY, Doubled marketable bulb yield; TMBY, Total marketable bulb yield. Treatments means followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of significance.

Higher yields from closer spacings or higher plant density had also been reported by several authors like Rashid and Rashid (1978), Shanthi and Balakrishnan (1989), Rumpel and Felczynski (1996), Karim *et al.*(1999), Kanton *et al.*(2002), Khan *et al.*(2003) and different experiments conducted in Bangladesh (BARI, 1992,1998 and 2007). While marketable yield increased with plant density and depending on year was highest at 80 or 100 plants m^{-2} (Rumpel and Felczynski, 1996) and increase in marketable bulb yield at densities above 76.92 plants m^{-2} was reported by Kanton *et al.* (2002). The interaction effect of varieties and spacings was not found to be statistically significant in case of total marketable bulb yield per ha.

Economic analysis of off season onion production

Higher number of seedlings required for closer spacing increased the cost of seedling production progressively as the spacing decreased. The cost of production of onion bulb in main field varied with the levels of spacing, the cost of planting and harvesting being the major determinant factors affecting the cost of bulbs production. The cost of production was highest (Rs. 2,93,754.60/ha) at the closest spacing (10×8 cm) and the lowest at the widest spacing (20×15 cm) i.e. Rs. 1,65,382.70/ha for AFDR while for N-53 spacing of 10×8 cm incurred the highest cost of Rs. 2,73,504.60/ha and the lowest cost of Rs. 1,59,982.70 /ha was observed at the spacing of 20×15 cm.

Total return varied with the yield. Higher yield level gave the higher income. The total return of Agrifound Dark Red and N-53 at the spacing of 10×10 cm while benefit cost (B:C) ratio of Agrifound Dark Red and N-53 was highest at the widest spacing of 20×15 cm and lowest at the closest spacing of 10×8 cm. The lowest B:C ratio at the closest spacing was due to the higher cost of seedling production as well as main plot production which progressively increased with the increase in spacing due to the lowered cost of production as the seedling production cost and main plot production cost considerably decreased as the spacing increased.

Gross income (Net returns) was also higher in Agrifound Dark Red as compared to N-53. Gross income of Agrifound Dark Red at the spacing of 12×10 cm was highest (Rs. 5,68,977.40/ha) and at the widest spacing of 20×15 cm it was observed to be the lowest (Rs. 4,63,798.40/ha). For N-53, the highest gross income was found to be Rs. 4,33,883.90/ha at the spacing of 10×10 cm as compared to the lowest gross income of Rs. 3,31,417.40/ha at the widest spacing of 20×15 cm. For AFDR, the gross income increased upto the spacing of 12×10 cm after which it declined progressively at closer spacings of 10×10 cm and 10×8 cm while for N-53, the gross income increased upto the spacing of 10×10 cm after which it declined at the spacing of 10×8 cm.

CONCLUSION

Though not significant, the number and percentage of the single marketable bulbs per plot was higher in AFDR while the number and percentage of doubled marketable bulbs per plot was significantly higher in N-53. The highest number of single marketable bulbs and total marketable bulbs per plot were produced at the spacing of 10×8 cm (91.67 and 95.50 respectively) which were not significantly different from those of 10×10 cm i.e., 90 and 95 respectively. Significantly higher number of bulbs in grade III (12.12) and grade IV (4.39) were seen in variety AFDR while significantly higher weight of bulbs in grade II, III and IV in variety AFDR as compared to N-53. Highest number, percentage by number, weight and percentage by weight of single marketable bulbs in grade I was found at the closest spacing of 10×8 cm while the highest numbers of bulbs in grade II were seen at the spacing of 10×8 (52.50) and 10×10 cm (51.67) which were at par. Highest weight (2.19 kg) and percentage weight (65.866%) of the single marketable bulbs in grade II was seen at the spacing of 10×8 cm which were not significantly different from 2.17 kg and 63.01% respectively at the spacing of 10×10 cm. Highest number, percentage by number, weight and percentage by weight of single marketable bulbs in grade IV were seen at the spacing of 20×15 cm.

The final plant stand, biological yield, TSS and dry matter percentage were significantly higher in the variety AFDR as compared to N-53. The final plant stand was significantly higher (122) at the spacing of 10×8 cm and lowest (42.84) at the spacing of 20×15 cm. Biological yield per plot was highest (6.24 kg) at the spacing of 10×10 cm which was not significantly different from 6.18 and 5.80 kg at the spacings of 10×8 and 12×10 cm respectively. Spacing had no significant effect on the TSS and dry matter percentage of the onion bulbs. Doubled marketable yield per plot was highest at the spacing of 20×15 cm while the single marketable yield per plot and total marketable yield per plot as well as marketable yield per ha was highest at the spacing of 10×10 cm which were not significantly different from those of 10×8 and 12×10 cm. Closer spacings produced significantly higher yield than wider spacings. The Grade II bulb yield showed similar pattern with the total marketable bulb yield per hectare with respect to spacing which increased with the decrease in spacing.

On the basis of economic analysis, variety AFDR performed better than N-53. Total cost of production was higher in AFDR because of the higher seed cost as compared to N-53. The cost of production was highest (Rs. 2,93,754.60/ha) in AFDR at the spacing of 10×8 cm and lowest (Rs. 1,65,382.70/ha) at the spacing of 20×15 cm. Similarly, for variety N-53, highest cost of production (Rs. 2,73,504.60/ha) was observed at the spacing of 10×8 cm and lowest (Rs. 1,59,982.70/ha) at the spacing of 20×15 cm. The highest net return per hectare for AFDR was observed (Rs. 5,68,977.40) at the spacing of 12×10 cm and for N-53 the highest net return of Rs. 4,33,883.90 was observed at the spacing of 10×10 cm.

From the present study, variety AFDR was found better than N-53 in different yield and yield attributes for off season onion bulb production. For both the varieties, the bulb size showed a general increase with increase in spacing. On the basis of single marketable bulb yield and total marketable bulb yield, planting density of around 84 to 125 plants m^{-2} is found suitable. Plant

population of 100 to 125 plants m^{-2} is found suitable for maximum yield of medium sized or highly marketable sized bulbs.

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