INFLUENCE OF METHOD OF PROPAGATION, NITROGEN FERTILITY LEVEL, AND ROW SPACING ON THE SIZE AND YIELD OF BULB ONION (*Allium cepa* L.)

by

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INTRODUCTION

Onion is one of the most widely grown vegetable crops in the world and the United States leads in production. While the acreage planted has declined since 1949, total production has increased and crop value has increased dramatically (37). The production increase with the reduction of planted acreage can be attributed to improved varieties and cultural practices. As more land is being taken out of cultivation, it is important to maintain production to meet consumer demand.

Some ways of increasing onion production include the selection of propagation methods concurrent with the type of production desired. Maturity is hastened by using transplants, but transplanting is less economical than direct seeding (4). However, early bulbs draw a higher market price (37).

The spacing at which plants are grown has an important influence on yield, and with many vegetable crops, including onion, there can be effects on other aspects such as the size of the marketable product. Growers using wide rows were aware that yields were often reduced, but the use of herbicides and multiple row planters and cultivators has decreased the need for wide row spacings (19).

Nitrogen, at optimum levels, has also been found to increase yield of onion bulbs. Numerous studies involving nitrogen, phosphorus and potassium individually and in combination have been conducted and nitrogen was found to have the most pronounced effect on increasing the yield of onion bulbs (29).

The objectives of this study were to determine optimum cultural practices for onion by evaluating:

(1) The effect of propagation method on the size and yield of onion bulbs;

(2) The effect of row spacings on the size and yield of onion bulbs; and

(3) The effect of nitrogen fertilizer applications on the size and yield of onion bulbs.

LITERATURE REVIEW

Transplanting versus Direct Field Sowing

A large part of the bulb onion crop in the United States is grown from seed sown where the crop is to mature. Direct seeding provides the lowest cost of production and is used almost exclusively for growing late market bulbs and the storage crop (4). Total yields and yields of U.S. No. 1 onions can be increased by using the transplant method (12). Other advantages gained by transplanting are an earlier crop, a uniform stand and bulbs of a more regular size. Onions for early and intermediate marketing in California are generally grown from transplants (8).

Influence of Nitrogen on Bulb Yield and Size

Many studies have been conducted on the influence of nitrogen, phosphorus and potassium in combination and individually on the bulb onion. Depending on the variety and region of research, many fertilizer recommendations have been made. In nearly all cases, the addition of nitrogen is superior to other nutrients in improving characters and yield of onion (14, 17, 18, 20, 21, 22, 24, 25, 26, 28, 30, 32, 33, 34, 35, 38).

In earlier fertilizer investigations on onion, Hawthorn (11) determined that phosphoric acid had the most effect on onion yield. Since that time, phosphorus has proven to increase yields when used in combination with nitrogen, but nitrogen has the dominant effect (17, 18, 21, 22, 26, 28, 33, 35). Potassium does not increase onion bulb yield and can have a depressing effect (22, 32, 25).

For optimum yield, recommended rates of nitrogen under varying conditions in India include 45 kilograms nitrogen per hectare (kg N/ha) (35), 67.2 kg N/ha (32) and 168 kg N/ha (21). Philippine workers (18, 26) obtained highest yield of Granex onion with applications of 100 kg/ha ammonium sulphate (21% N) and rates above 150 kg/ha did not significantly affect onion yield.

Yields of bulbs over 4 cm in diameter were increased when N levels increased from 56 to 168 kg/ha (21) and in experiments by Das and Dhyani (5), the optimum N level for bulbs that would draw the best market value was 67 kg N/ha.

Influence of Plant Spacing on Bulb Yield and Size

Plant spacing influences the growth of each plant and may be reflected in yield and size of the marketable product. Most investigations with onions have been concerned with intrarow spacing of the plants in conjunction with interrow spacing, thus relating bulb size and yield to number of plants per unit area. Bleasdale (3) in Great Britain found that the total yield of ripe bulbs increased with increasing number of plants per square meter until an optimum is reached and, thereafter, declines. At plant densities optimum for total yield, the bulbs were too small for normal market but were suitable for pickling whole. Decreasing the distance between rows at a given plant density increased the total yield of bulbs. At 7 plants per .09 square meter reducing the row spacing from 46 to 23-30 cm increased yield by 10-30%.

Frappell (9) determined that at all densities there is a range of onion sizes produced, but as density increases there is a progressive shift from large grades to smaller grades. Obviously, plant density cannot be used to produce a crop totally within a limited size range of bulbs, but it may be used to exert a considerable effect on size-grade distribution. Frappell and Cox (10) indicate that 6 plants per .09 square meter should be used under average growing conditions for maincrop onions using present recommended cultural methods. This gives an optimum plant density to obtain a majority of bulbs larger than 4.4 cm in diameter and to obtain greater total crop yield.

In India, Patil and Chavan (23) reported that Nasik Red onion at 15 x 7.5 cm plant spacing gave medium size bulbs with uniform maturity, better keeping quality and a lower percentage of culls.

In the United States, Jones (14) reported that as the space between plants in a 46 cm row increased from 7.5 cm to 30 cm there was a delay in the time of maturity, an increase in the size of the bulbs and a decrease in yield per hectare and Hawthorn (12) reported that close row spacing increased yields. Lucas' (19) work in onion spacing and population studies indicated that the best yield for onions over 5 cm in diameter was obtained at a population of about 555,750 plants per hectare or about 175 square cm per plant.

Effect of Nitrogen and Row Spacing on Onion Bulb Yield and Size

In experiments by Das and Dhyani (5), the onion yield was affected by spacing and nitrogen levels. Effect of N levels was also significant on all bulb sizes, while the effect of spacing was marked on bulbs of maximum and minimum sizes only. Plants with the maximum 30 cm spacing in rows 30 cm apart yielded higher bulb weight totals per plot but when converted to hectare basis, yield was lower. The reason for this was that plot weight was determined by length of row only and on a hectare basis both length and width was used to determine yields. The least spacing of 10 cm yielded the highest weight of bulbs at time of harvest but bulbs were of poor size. Nitrogen requirement was optimum at 67 kg/ha. Recommendations of 67-90 kg N/ha with 23 cm spacing for best market value and 10 cm spacing for highest tonnage were made.

Other recommendations for plant spacing and nitrogen levels vary. Randhawa and Singh (27) report that 15 x 10 cm spacing produced highest total bulb yield and this yield was increased with applications of N up to 75 kg/ha. Ahlawat and Singh (1) determined that highest yield of bulbs was obtained with 80 kg N/ha and 10 cm spacing. 120 kg N/ha applied to the onion crop planted at a spacing of 8 x 20 to 12 x 20 cm is recommended by Das, Behera and Sahoo (6).

Influence of Leaf Area on Bulb Yield and Size

Increases in leaf number and fresh and dry weight accompany increases in N level and spacing (5, 6, 21, 22, 29, 32). In defoliation studies by Hawthorn (13) and Baker and Wilcox (2), bulb yield and bulb size was reduced by the removal of leaf tissue. Leaf emergence ceases about the time bulb formation begins so the size of bulb is dependent on the number of leaves present at that time.

MATERIALS AND METHODS

Allium cepa L. 'Yellow Sweet Spanish' was planted at Ashland Horticultural Farm, Kansas State University, on a Sarpy fine loam that receives 81 cm average, annual rainfall. Seeds or transplants of onions were planted in rows 30, 60 or 90 cm apart, and nitrogen was applied at 56, 112 or 168 kg/ha, total, over the season of 1976.

Each propagation method was replicated four times within the split plot design and contained each row spacing. Within each row spacing were the nitrogen levels in three rows, each separated by a guard row, making 18 treatments in all. Two guard rows were planted on the outsides and one between N plots.

Fifty-six kg N/ha was applied to all treatments before planting; the remaining N was sidedressed with 56 kg N/ha applications when the onions were 15 cm tall and again when they were 30 cm tall. Ammonium nitrate (33% N) was the fertilizer source for nitrogen applications.

Fifty-six kg P/ha as triplesuperphosphate (46% P_2O_5) was applied as a preplant application.

Seeds were planted at approximately 2 cm spacing within the row with a Planet Jr. seeder. The transplants were set by hand at about 7.5 cm spacing within the row. Seeds were planted 30 March and transplants set 1 April.

The crop was hoed and irrigated when needed (Table 1) and sprayed regularly with Sevin and Thiodan for insect protection. DCPA was applied early and nitrofen later in the season for weed control.

Two-hundred ten cm of the plot row was harvested when 25% of the tops had fallen over. Transplanted plots were harvested on 20 July and seeded plots on 20 August. The tops and roots were removed and bulbs graded according to diameter in centimeters as follows: greater than 7.5, 5.0-7.5, 2.5-5.0 and less than 2.5. The weight and number of each classification were recorded. The number of leaves on ten plants taken at random was recorded for each plot.

Weather information for the cropping period is given in Tables 2 and 3.

RESULTS

Yield per hectare by weight was taken for three bulb diameters; greater than 7.5 cm, 5.0-7.5 cm, and 2.5-5.0 cm, and for total yield. Transplanted onions yielded significantly more per hectare in all but the 2.5-5.0 cm bulb diameter class and were harvested one month earlier (Table 4). Total yield and yield of bulbs 5.0-7.5 cm diameter increased as row spacing decreased from 90 to 30 cm. Yield of bulbs larger than 7.5 cm in diameter was favored by 60 and 90 cm row spacing and yield of bulbs 2.5-5.0 cm in diameter by 30 cm spacing (Table 5). Greater nitrogen levels significantly increased total yield, with 112 and 168 kg N/ha being equal and better than 56 kg N/ha (Table 6).

Highest total yields were obtained with transplants and seeds in 30 cm rows followed closely by transplants in 60 cm rows. Lowest total yields were of seeded and transplanted plots in 90 cm rows followed closely by seeded plots in 60 cm rows. No bulbs larger than 7.5 cm in diameter were harvested from direct-seeded plots. As spacing increased, the yield of bulbs 5.0-7.5 cm diameter from direct-seeded plots did not change; but, for transplanted plots, the yield decreased. For bulbs 2.5-5.0 cm diameter, the yield from seeded plots decreased and the yield from transplanted plots decreased as spacing increased from 30 to 60 cm (Tables 7, 8 and 9).

The interaction of propagation method, row spacing and nitrogen level was significant only on bulbs 5.0-7.5 cm in diameter. For either planting method and any nitrogen level, the yield was the same at 90 cm. For seeded plots, the yield didn't change as the spacing increased. Yields from transplanted plots increased as spacing decreased except at the 30 cm spacing where 56 kg N/ha yielded equally with the 60 cm spacing at the same nitrogen level (Table 10).

Transplanted onions had a greater number of leaves per plant than those seeded directly (Table 11) and, as spacing increased, the number of leaves per plant increased (Table 12).

DISCUSSION

Onion bulbs grown from transplants had consistently higher total yields and yields of bulbs larger than 5.0 cm in diameter than onions seeded directly in the field. Hawthorn (12) also found that total yields and yields of U.S. No. 1 onions were increased by using the transplant method. Transplanted onions had more leaves at harvest than the direct-seeded plants, which may, in part, explain the higher yield of large sized bulbs. Baker and Wilcox (2) and Hawthorn (13) stated that bulb size was dependent on the number of leaves present at the time of bulb initiation. Bulb formation begins in response to photoperiod (15), so bulbs would be initiated at the same time in both transplanted and direct-seeded crops. Leaf formation ceases when bulb formation begins so bulb size is determined by the number of leaves present at the time of bulbing. Comin and Davis (8) also obtained earlier crops when transplants were used as the propagation method. The month the direct-seeded plants took to establish themselves was used by the transplants to add leaves.

The low yield of large bulbs from direct-seeded plants could be due to plant competition. The seeding rate was 16.0 kg/ha at 30 cm row spacing, 8.0 kg/ha at 60 cm and 5.3 kg/ha for rows spaced 90 cm apart. Recommended seeding rates are 5.5-7.3 kg/ha at row spacings of 45-90 cm (16). The 30 and 60 cm row spacings were seeded well above recommended rates. This over-compensation was to insure a good stand. They were not thinned because on a commercial basis this practice is not economically feasible. Transplants were spaced at 7.5 cm in the rows and were favored by the increased area per plant.

The importance of spacing in onion cropping is recognized by a number of workers (1, 3, 5, 6, 7, 9, 10, 12, 23, 27). The basis of most of this research is on number of plants per unit area or with intrarow plant spacing varying rather than the row spacing itself; Hawthorn (12) is the only exception. He reported that close row spacing increased yields. In this study, the 30 cm row spacing did produce higher total yields. At this spacing, those transplanted onions produced enough bulbs over 5.0 cm diameter to be classified as U.S. No. 1 (31); direct-seeded plots did not, possibly for the reasons discussed previously. As row spacing increased, total yields decreased, but the yield of bulbs larger than 7.5 cm in diameter was favored by the wider row spacings. Frappell (9), Jones (14) and Bleasdale (3) all reported that larger bulbs are produced at wider spacings, but that total yield per hectare declines. Accordingly, at plant densities optimum for total yield, the bulbs are too small for normal market (3, 5). Leaf number increased as spacing increased and at these spacings, larger bulb sizes were evident. This situation has been observed by others (5, 6, 21, 22, 29, 32). The reasons for this size increase are similar to leaf number and bulb size increase in transplanted onion.

Nitrogen, in varying amounts, has been found to increase yield and bulb size in onion (14, 17, 18, 21, 22, 26, 28, 30, 32, 34, 35). In this study, nitrogen applied at 112 kg/ha gave optimum yield increases, but no effect on bulb size was found. Nitrogen was not more advantageous to one propagation method than the other, but increased the total yield at 30 cm row spacing. Apparently, populations at this density require more nitrogen to obtain maximum yield. As plant populations increase there is less area for the plant to draw nutrients from so they require more fertilizer (36). Das and Dhyani (5), Randhawa and Singh (27), Ahlawat and Singh (1) and Das, Behera and Sahoo (6) have all demonstrated this in onion and have made specific recommendations.

The data from this study indicate that optimum yields of U.S. No. 1 grade onions can be obtained by transplanting onions at 30 cm row spacing and applying 112 kg N/ha during the growing season. No literature on onions including these three variables was found, but from research on individual effects and on the combination of nitrogen level and plant spacing, these results seem feasible. Direct-seed planting could give comparable total yields under these same conditions, though bulbs would be smaller. This could be due to a fewer number of leaves at the time bulbing is initiated. Reduced seeding rates might increase bulb size but it is questionable if they would be as large as transplant onions.

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TABLES

Table 1. Irrigation dates.[1]

April 2, 6, 16
June 7
July 9, 26
August 8

[1]Two cm per application.

Table 2. Weekly, mean maximum and minimum atmospheric temperatures (^{o}C).

Date	April		May		June		July		August	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1-7	22.1	4.6	20.6	5.9	28.3	14.4	28.5	16.7	29.9	17.8
8-14	23.3	8.9	22.4	7.9	32.6	20.4	33.7	21.8	35.2	22.3
15-21	21.1	10.6	23.6	11.5	27.7	13.2	31.2	20.0	34.8	20.5
21-30, 31	17.6	8.9	23.4	13.2	29.8	17.3	35.6	22.2	33.8	18.5

Table 3. Monthly precipitation totals for April--August, 1976 (cm).

April	May	June	July	August
15.3	9.8	15.1	2.9	0.7

Table 4. Effect of propagation method on yield and bulb size of direct-seeded and transplanted onion crops in tons/hectare.

Propagation method	Marketable bulb size (cm)		
	5.0-7.5	2.5-5.0	Total
Direct-seeded	8.9	14.0	29.4
Transplanted	21.1	3.1	34.5
$LSD_{.05}$	2.5	1.9	2.7

Table 5. Effect of row spacing on yield and bulb size of direct-seeded and transplanted onion crops in tons/hectare.

Row spacing (cm)	Marketable bulb size (cm)			
	7.5	5.0-7.5	2.5-5.0	Total
30	4.7	18.8	13.5	41.2
60	13.5	15.5	7.1	32.1
90	10.2	10.7	5.0	22.4
$LSD_{.05}$	5.3	3.1	2.4	3.3

Table 6. Effect of nitrogen level on yield and bulb size of direct-seeded and transplanted onion crops in tons/hectare.

Nitrogen level (kg/ha)	Marketable bulb size (cm)			
	7.5	5.0-7.5	2.5-5.0	Total
56	6.3	13.1	7.2	27.8
112	9.8	16.5	8.6	33.4
168	12.2	15.4	9.8	34.6
$LSD_{.05}$	NS	NS	NS	3.3

Table 7. Effect of propagation method and row spacing interaction on yield and bulb size of onion crop in tons/hectare.

Row spacing (cm)	Propagation method	Marketable bulb size (cm)		
		5.0-7.5	2.5-5.0	Total
30	Direct-seeded	7.8	20.7	40.1
	Transplanted	29.8	6.2	42.4
	$LSD_{.05}$	9.5	4.9	NS
60	Direct-seeded	9.6	12.6	26.9
	Transplanted	21.4	1.7	37.3
	$LSD_{.05}$	9.5	4.9	9.6
90	Direct-seeded	9.4	8.8	21.1
	Transplanted	12.1	1.3	23.9
	$LSD_{.05}$	NS	4.9	NS

Table 8. Effect of row spacing on yield and bulb size of direct-seeded onion crop in tons/hectare.

Row spacing (cm)	Marketable bulb size (cm)		
	5.0-7.5	2.5-5.0	Total
30	7.8	20.7	40.1
60	9.6	12.6	26.9
90	9.4	8.8	21.1
$LSD_{.05}$	NS	3.3	4.6

Table 9. Effect of row spacing on yield and bulb size of transplanted onion crop in tons/hectare.

Row spacing (cm)	Marketable bulb size (cm)		
	5.0-7.5	2.5-5.0	Total
30	29.8	6.2	42.4
60	21.4	1.7	37.3
90	12.1	1.3	23.9
$LSD_{.05}$	4.3	3.3	4.6

Table 10. Effect of propagation method, row spacing and nitrogen level interaction on yield and bulb size on onion crop in tons/hectare.

Nitrogen level (kg/ha)	Row spacing (cm)	Propagation method	Marketable bulb size (cm)		
			5.0-7.5	2.5-5.0	Total
	30	Direct-seeded	8.2	15.6	35.3
		Transplanted	19.6	6.1	30.6
56	60	Direct-seeded	9.2	10.5	26.2
		Transplanted	22.3	2.3	33.3
	90	Direct-seeded	7.3	7.9	19.5
		Transplanted	12.0	1.2	22.3
	30	Direct-seeded	8.6	21.8	41.4
		Transplanted	33.2	5.8	47.7
112	60	Direct-seeded	9.0	13.5	26.8
		Transplanted	23.6	0.9	39.8
	90	Direct-seeded	10.5	8.4	21.1
		Transplanted	14.4	1.2	23.4
	30	Direct-seeded	6.6	24.6	43.5
		Transplanted	36.5	6.8	48.9
168	60	Direct-seeded	10.7	13.7	27.8
		Transplanted	18.3	2.0	38.8
	90	Direct-seeded	10.3	10.0	22.7
		Transplanted	9.7	1.6	26.0
		$LSD_{.05}$	7.5	NS	NS

Table 11. Effect of propagation method on average number of leaves per plant.

Propagation method	Number of leaves
Direct-seeded	5.5
Transplanted	7.5
$LSD_{.05}$	0.3

Table 12. Effect of row spacing on average number of leaves per plant.

Row spacing (cm)	Number of leaves
30	5.8
60	6.5
90	7.1
$LSD_{.05}$	0.4

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Onion (*Allium cepa* L.) is a widely grown vegetable crop in the United States and the world. While planted acreage has declined, total production has increased. The objective of this study was to determine how yields could be increased by comparing propagation methods, row spacings and nitrogen fertility levels.

Allium cepa L. 'Yellow Sweet Spanish' seeds or transplants were planted in rows 30, 60 or 90 cm apart, and nitrogen was applied at 56, 112 or 168 kg/ha, total, over the season of 1976. The bulbs were graded according to diameter in centimeters as follows: greater than 7.5, 5.0-7.5, 2.5-5.0 and less than 2.5. The weight and number of each classification and an average number of leaves per plant for each plot were recorded.

Onion bulbs grown from transplants had consistently higher total yields and yields of bulbs larger than 5.0 cm in diameter than those seeded directly in the field and had more leaves at harvest.

As row spacing increased, total yield decreased, but the yield of bulbs larger than 7.5 cm in diameter was favored by the wider row spacings. Leaf number increased as spacing increased and at these spacings larger bulbs were evident.

Nitrogen applied at 112 kg/ha gave optimum increases, but no effect on bulb size was found.

The data from this study indicated that optimum yields of U.S. No. 1 grade onions can be obtained by transplanting onions at 30 cm row spacing and applying 112 kg N/ha during the growing season. Direct-seed planting could give comparable total yields under these same conditions, though bulbs would be smaller.