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Studies on effect of varieties, transplant ages and transplant densities on growth, yield and quality of Rabi onion (*Allium cepa* L.): A review

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Abstract
An attempt has been made to collect available literature on performance of onion in relation to different agro techniques adopted in light of present study to support the findings. Onion is one of the most important spice crops of the world. The production of onion is influenced by many factors, such as, varieties, transplant ages and transplant densities. Among them varieties, transplant ages and spacing are one of the most important factors for production of onion. Onion varieties respond differently to day length and photoperiods in a particulate environmental condition. Proper age of seedling can produce better yield of bulb (Thomson and Kelly, 1957, Maurya *et al*., 1997 and Singh and Chaure, 1999). Kanton *et al*. (2002) found that maximum yield was produced from transplants seedlings that were of 20 to 40 days old and significantly 40 days old transplant seedling produced heaviest bulbs. Higher yield and better control over bulb size could be obtained if plants are grown at optimum density. Spacing influences the plant growth, size of bulbs, yields as well as the quality of the onion bulb (Badruddin and Haque, 1977).

Keywords: Varieties, transplant ages, transplant densities and quality

1. Introduction
Onion (*Allium cepa* L.) is the most common member of the family Amaryllidaceae (Alliaceae) (Hanlet, 1990) [18]. It is one of the most important vegetable crops grown throughout the world and said to be native of Central Asia and Mediterranean region (McCollum, 1976). It is widely grown herbaceous biennial vegetable crop with cross-pollinated and monocotyledonous behavior having diploid chromosomes number 2n=16 (Bassett, 1986) [6]. The name "Onia" is probably ranked to a city built by Onia in 1703 BC near the Gulf of Suez. Onion can be used as green or scallion or as a mature bulb. Green onion may be cooked or used raw as part of salads and mature also used as salad bulbs are widely used as a cooked vegetable in soups, stews and casseroles in addition to a flavoring agent in many additional dishes.

Onion possesses nutritional and medicinal importance. The onion has much quality and medicinal properties characteristic of onion is its pungency, which is due to a volatile oil known as (Allyl–propyl-disulphide). Onion is a rich source of various nutrients and vitamins, all the plant parts are edible, but the bulbs and the lower stem sections are the most popular as seasonings or as vegetables in stew fresh onion contains about moisture (86.6%), protein (1.2%), fat (0.1%), mineral matter (0.4%), fibre (0.6%), carbohydrates (11.1%) including 6-9 soluble sugar, calories (50 kcal), phosphorus (50mg/100g), potassium (127 mg/100g), calcium (46.9mg/100g), magnesium (16mg/100g), iron (0.6mg/100g), sodium (4mg/100g), copper (0.18mg/100g), vitamin C (11mg/100g), niacin (0.4mg/100g), thiamine (0.08mg/100g), riboflavin (0.01mg/100g), folic acid free (15mg/100g) and folic acid total (6mg/100g), traces of Al, Cu, Fe, Mn, Zn, pantothenic acid and vitamins (A, B, and C, respectively) (Rahman *et al.*, 2012) [44]. The production and productivity of onion in Chhattisgarh is low in comparison to other states. The production of onion is affected due to several factors like varieties, sowing time of nursery, transplanting time, seedling age, plant geometry and several other cultural practices, all of which alone or in combination influence the crop yields. Very meager information is available on the effect of such kind of factors particularly under with reference to agro climatic conditions Chhattisgarh.

2. Review of literature

2.1 Effect of varieties

1. Effect of varieties on growth, yield attributes and yield
2. Effect of varieties on quality characters

2.2 Effect of transplant ages

1. Effect of transplant ages on growth, yield attributes and yield
2. Effect of transplant ages on quality characters

2.3 Effect of transplant densities

1. Effect of transplant densities on growth, yield attribute and yield
2. Effect of transplant densities on quality characters

3. Effect of varieties

3.1 Effect of varieties on growth, yield attributes and yield

Different cultural practices and growing environments are known to influence growth and yield of onion. So far, research in the country was mainly focused on the identification of superior cultivars of onions and adopting improved management practices. Mohan *et al.* (1975) [31] recorded that the cultivar Aggregatum Co-2 produced 10.1 splitted bulb per-clumps, the number of bulbs clump^{-1} were 8 to10 and 9 to10 in the cultivar Aggrigatum Co-2 and Co- 3, respectively. Muthukrishaan and Rajagopal (1978) [32] studied few cultivars of onion and observed that the average yield of 20.83, 20.59, 20.25, 16.60, 15.74, 13.19, 10.80, 10.72 and 9.17 t ha^{-1} were found in the cultivar Ballery Red, N-53, Udaipur-101, Pusa Ratnar, Pusa Red, Patna Red, Kalyanpur Red, Punjab Selection and Selection-102, respectively. Pandian *et al.* (1979) [36] reported that the average individual bulb weight of 75 g and 60 g was recorded in the cultivar Aggregatum Co-3 and Co-2, respectively. The Udaipur Local produced maximum number of splitted bulbs (26.29%) followed by the cultivar Hisaar-2 (14.60%) and minimum was recorded in the cv. N-53 (1.04%).

Rahim *et al.* (1980) [43] reported that the varieties like Udaipur Local, Hissar-2 and N-53 took 125 days from transplanting to harvesting. The average yield of 13.33, 9.13 and 7.65 t ha^{-1} was found in the cultivar N-53, Hissar- 2 and Faridpuri Local, respectively. Mishra and Pandey (1980) [30] studied the color of different cultivars of onion and reported that the varieties N-53, Punjab Selection, Agrifound dark red were deep red and red in colour, while the varieties Selection 11 and Selection 14 were deep pink and pink, respectively. Vavidel *et al.* (1982) [15] reported that the cultivars Aggregetum AC-863 (6-9), Co-3 (8-10) and Co-2 (8-11) contained number of bulbs clump^{-1} respectively. Gupta and Hiralal (1985) reported that the yields of the cultivars like N-53, Pusa Red, Pusa Ratnar and Nasik Red varies in between 280-340 q ha^{-1}. Sindhu and Chadha (1985) [49] recorded that the average yields of 250-300 and 200-250 q ha^{-1} was found in the cultivar Punjab-48 (*rabi*) and N-53 (*kharif*) respectively. The varieties Punjab Selection, PLRG selection were shining red in colour, while White Globe Selection and Punjab-48 were white in colour. In another report it was found that the varieties Agrifound Light Red, Line-102 was light red in colour, while Arka Kalyan and Arka Pragati were pink in colour. Patil *et al.* (1987) [39] studied 45 different onion cultivars and reported that the highest bulb weight of 125. 33g was found in the cultivar Udaipur-102 followed by No-4-2-G 119.07g and Dangawade 113. 40g. the lowest bulb weight of 81.33g was recorded with the cultivar Pusa While Flat They suggested that the size of bulbs varies from cultivar to cultivar. Chadha *et al.* (1989) [9] reported that the average yield of 255.36 q ha^{-1} was found in the cultivar Punjab Red Round which was 26.49 per cent higher than the cultivar Punjab Selection. Gill *et al.* (1989) [16] reported that the average yield of 337, 335, 300, 300-325 and 250-300 q ha^{-1} was found in the cultivar Arka niketan, Arka kalian, Pusa White Round, Agri found Light Red and Kalyanpur Red, respectively.

3.2 Effect of varieties on quality characters

Karmakar and Joshi (1941) [24] noted 0.78 per cent of protein content in onion. Choudhary (1967) [11] stated that the protein content of onion bulb was 1.2 g per 100 g of edible portion. The ascorbic acid content of onion bulb was 11 mg per 100 g, the protein content of 1.3 g and 2.0 g per 100 g edible portion in the onion bulb and green leaves, respectively was also reported by Masymaguchi (1983) [27]. Pathak *et al.* (1973) [37] reported that the ascorbic acid content of the edible portion of the fresh onion bulb was 7.93 mg per 100 g, and moisture content of onion varies from 85-90%. Sandhu *et al.* (1975) [47] reported that the T.S.S. content of Patna Red, Punjab Selection and Pusa Red, was 13.04, 11.06 and 11.2 percent, respectively. Muthukrishnan *et al.* (1978) [32] evaluated 16 onion cultivars and found that the T.S.S content of the cultivar ranged from 9.4 to 12.2 per cent. The highest T.S.S. content was found in Ballory Red (12.2%) followed by Punjab Selection (11.3%), while the lowest was found in Hissar-11 (9.4 %).

Patil *et al.* (1978) [38] observed the genetically variance of a set of 45 onion cultivars and recorded that the reducing sugar content ranged from 2.1 to 2.39 percent. The highest reducing sugar content was found in the cultivars Pusa White flat and Jalagaon (2.39%), while the lowest was recorded in the cultivar Dangawade-1 (2.13%). Pandian *et al.* (1979) [36] studied the reducing sugar content of the cultivar Aggregatum Co-3 and Co-2 were 1.28 and 1.10 percent, total sugar 13 and 4.48 percent, acidity content 0.205 and 0.200 percent, ascorbic acid contents of 10 mg, moisture percent 100 g edible portion 82.5 and 84.4 percent, respectively. Bajaj *et al.* (1980) [5] reported that the reducing sugar content in onion cultivars varied from 12-22.25 percent. Masyamaguchi (1983) [27] stated that the ascorbic acid content of green bulb and green leaves were 32 mg and 45 mg and moisture content of 90 g and 92 g per 100 g was found in the onion bulb and green leaves, respectively. Mishra and Maurya (1985) studied the T.S.S. content of onion varieties and reported that the T.S.S. content of 10.01, 10.08-11.08, 12.14 and 4.6-13.9 percent were found in the cultivar N-53, Punjab Selection, Patna Red and Hissar-11, respectively. Bose and Som (1986) reported that the protein content of the bulb was 1.2 g and in stalk 0.9 g per 100 g. Kandil *et al.* (2010) [22] indicated that Giza 20 and Composite 9 had the heaviest bulb weight, followed by Giza Red. Highest percentages of TSS and dry matter % were obtained from Giza White, followed by Giza 20. Giza 20 cultivar was associated with maximum total bulbs yield and marketable yield, followed by Composite 9. Azoom *et al.* (2014) [2] noted the significant differences among eight onion varieties for days to bulb maturity. Bombay Red and Adama Red matured by less than 120 or in between 110 to 130 days, respectively (EARO, 2004).

4. Effect of transplant ages

4.1 Effect of transplant ages on growth, yield attributes and yield

Thompson and Kelly (1957) [52] suggested that 42 to 70 days old seedlings should be planted. Yu and Ts Eng (1966) [60]

planted onion seedling ranging in age from 25 to 60 days. They observed quickest growth, earliest maturity and largest bulb in the seedling aged 30 days in China. Patil *et al.* (1958) [40] observed that transplanting of variety Nasik Red onion was increased by one-week from 7 to 14 weeks. There was progressive increase in yield in two out of three experimental years at Puna. They suggested that 56 to 63 days old seedlings should be transplanted in a study at Nainital, India. Verma *et al*. (1971) [56] transplanted seedlings at the age of 4. 6, 8 and 10 weeks respectively and observed that 8 weeks old seedlings gave the highest yield of bulb. Ahmad and Rashid (1976) [45] suggested that, 30 and 45 days old seedling should be transplanted for the production of onion bulb.

Vachhani and Patel (1989) [53] conducted field trials with the cultivar Pusa Red and reported that the yield increased with seedling age from 257.7 q ha^{-1} with 4 week old seedlings to 462.3 q ha^{-1} with 7 week old seedlings, but then decreased gradually to 325.3 q ha^{-1} with 10 week old seedlings. Paul *et al.* (1990) [41] reported that the significant differences among the varieties were present in respect to period required for emergence of flower stalk. The variety N-51 took significantly less days 63.64, while maximum day was taken in variety Linc-102, 6Lujan studied on planting date and transplant age with a white Grano cultivar, and observed the highest yields from seven week old transplants set in mid September. Lujan-Favela correlated yield with transplant size suggesting larger was better. Avodele (1993) [1] reported that transplanting of four week old seedlings of onion cultivar Red Crook or Texas Early Grano after the onset of rainy season on 6, 13, 20 or 27 April had no significant effect on bulb yield under humid condition of South West Nigeria. Ha *et al.* (1998) conducted an experiment with sowing date and age of seedling of onion. They worked with three age of seedling. Seedling quality improved as seedling age increased from 35 to 55 days. It was observed that seedling establishment was enhanced by young plug seedlings, higher rates of bolting and doubling of bulbs occurred with early sowing and old young seedlings.Sharma (1998) conducted an experiment with seedling age and nitrogen levels of onion. He used four, five, six and seven weeks old seedlings. Plant height, number of leaves $plant^{-1}$ and mean bulb yield increased significantly as seedling age at transplanting increased up to 6 weeks old.

4.2 Effect of transplant ages on quality characters

Bhattari *et al.* (1996) reported that the local variety Nasik Red showed more bolting compared to Mallajh. A physiological study on onion showed that early planting and use of aged seedlings induces pre-mature bolting on onion. In early planting, young seedlings (6 and 8 weeks old) did not bolt. Hence, bolting was found to be a function of planting time and seedling age during planting. Weed competition on onion production was studied as a major constraint to yield. Ha *et al*. (1998) reported that the best quality plug seedlings were obtained by sowing on 27th August in Chinju, Korea. Seedling quality improved as seedling age increased from 35 to 55 days. Higher rates of bolting and doubling of bulbs also occurred in mulch cultivation, with early sowing and young seedlings. On the basis of marketable yield, 5th September was the best time for sowing seeds, suggesting that best time for transplanting was 20-30 October under Chinju, Korea conditions. Bhonde *et al.* (2001) [8] carried out an experiment with onion on age of seedling 7, 8 and 9 weeks and date of harvesting 110, 125 and 140 DAT on yield and quality during late *kharif* season. Data were recorded for, bulb development, days to crop maturity, less bolting and doubling, bulb yield, bulb weight, dry matter percentage and total soluble solids. The used of 8 weeks old seedlings and harvesting at 125 DAT gave the best yield, quality and highest TSS compared with the other treatments. Singh *et al*. (2011) [50] reported that bolting was more in the treatment having 60 days old seedlings as compared to the 45 days old seedlings. Kumbhkar *et al*. (2012) [25] studied the effect of age of seedlings on growth, yield and quality of onion (*Allium cepa* L.) cv. Agrifound white with different age of seedling. The minimum bolting per cent (22.99) and maximum total soluble solids (14.47%) were observed higher with six weeks old seedling transplanting.

5. Effect of transplant densities

5.1 Effect of transplant densities on growth, yield attributes and yield

Optimum plant spacing is one of the most important and uncontroversial factors for maximizing the yield of a crop. The results of many studies relating to spacing of onion are reviewed below. Kelbart and Burgis (1962) found that a spacing of 5.08 cm in the row produced higher number of grade-1 bulbs which were more uniform in size than those spaced in 10.16 cm. The wider spacing was found to increase the bulb size and weight. Purewal and Dargan (1962) [42] stated that the closer spacing (17.62 cm x 15.00 cm) resulted in higher yield than wider spacing. They also observed that closer spacing produced the smaller bulb. Similar result was found by Verma *et al.* (1972), and their recommended spacing was 9 cm x 15 cm. Kamaluddin (1967) [57] noted that row spacing of 30.48 cm with 10.16 cm to 15.24 cm plant to plant distances in rows gave the highest yield. Khandelwal and Maiti (1971) found that the widest spacing increased the yield of onion $plant^{-1}$, but the closest spacing increased the yield of onion per hectare. Frappell and Cox (1973) conducted an experiment with plant population m^{-2} and reported that the optimum density for maximum yield was 107.53 plants m^{-2}. Funus *et al.* (1974) in Bangladesh conducted trial with onion seedlings transplanted at spacings of 5 cm x 20 cm, 10 cm x 20 cm, 15 cm x 20 cm and 20 cm x 20 cm. They obtained the highest yield from the closest spacing without heavy irrigation. Villagram and Escaff (1982) [58] conducted an experiment with five levels of nitrogen from zero to 120kg ha^{-1} and five levels of plant density from 2, 66, 666 to 8, 00.000plants ha^{-1}. The highest marketable bulb obtained was 571428 plants ha^{-1}. They observed there were no interaction between plant density and nitrogen rate. Wilson and Hutton (1983) [59] carried out an experiment on the effect of plant spacing on onion yield. In their three years trial, they obtained the best yield of large grade onion with the population of 45 to 70 plants m^{-2}. Above this level, the proportion of large bulbs (>57 mm diameter) decreased although the total yield increased.

Geary *et al.* (1985) [15] studied on planted onion cv. White Spanish under six different populations 178, 400, 632, 816, 1110 and 1600 plants m^{-2} and reported a decline in number of round bulbs (13.3%) when population increased from 178 to 1 600 plants m^{-2}. Current results showed that all the bulbs (100%) changed shape as plant population changed. Lopes (1987) worked with some short day onion varieties and suggested that the closer plant spacing gave the best yield of bulb. Zharekhina (1987) carried out an experiment and reported that the best yields (12.6 g m^{-2}) were obtained at plant Chaudhary *et al*. (1990) showed that maximug ha^{-1}) was produced at density of 80 plants $4m^2$ while, minimum yield of bulbs (5133 kg) ha^{-1} was recorded at planting density of 40

plants 4m^2. Fukai *et al*. (1990) revealed that full canopies, intercept more radiation and have a greater photosynthetic production than the partial canopy development which is observed in wider row spacing. Days to maturity described positive association with bulb yield Patil (1997). Verma *et al.* (1994) found that average branch length increased between the low and medium spacing. Farghali and Zeid (1995) [12] conducted field experiment in Egypt to find out the effects of onion with plant population and phosphorus fertilization. They found that average bulb weight and diameter decreased as the plant population increased. Kusumo and Widjajato (1999) at spacing of 15 x 15 cm and 15 x 10 cm. The best yield and quality were obtained with bulblets from medium sized bulbs at wider spacing. Hariom and Srivastava (2000) [19] observed in garlic crop that the maximum bulb yield was recorded under the spacing of 10 x 20 cm (112.58 q ha-1) which was significantly superior to spacings of 15 x 20 cm and 20 x 20 cm.

5.2 Effect of transplant densities on quality characters.

Bacvarov (1964) [3] conducted an experiment on onion and observed that the spacing of 15 cm x 15 cm produced the best quality bulbs. Vik (1970) [57] about "Frames and plant density trials in sowing onion" stated that the increasing plant density, maturity of plants was advanced, yield was increased and the bulb sizes were reduced. TSS and storage quality also improved with Rogers (1977) [46] identified that distde sizes in onion cannot be determined from mean weight, but will depend on the growth of individual plants within the population. Hassan (1978) [20] observed that wide spacing resulted in large bulbs which were more vulnerable to splitting than small bulbs produced by narrower spacings. They reported that bulbs from 1, 2, 3 and 4, rows per ridge had 42, 38, 21 and 16% doubles and from 5, 10, 15, and 20 cm in-row spacing, there were 16, 25 and 34, 38% doubles, respectively. Hatridge and Bennett (1980) [21] reported that higher yields were obtained at higher densities (100 plants m^{-2}) and low rectangularity. Naruka *et al*. (2003) [35] reported that, large size of bulb exhibited the highest weight loss compared to smaller size of bulbs. Nagre *et al*. (1985) [33] reported that Mid-December planting increased bolting to > 10%, mid-January planting resulted in < 1% bolting and a mid-February-planted crop was free of bolting. Spacing (15 X 10, 15 X 15 and 15 X 25 cm) did not affect bolting. Bulb splitting percentage was highest in December planting and lowest in February planting. They recorded that January planting at 15 X 10 cm gave the best yield and quality. Farrag *et al*. (1995) [14] emphasized that high planting density significantly increased single-bulb, double-bulb and total yields, as well as reducing bulb weight diameter.

Resende *et al*. (1999) worked on intra-row spacing and two onion cultivars and reported that when plant spacing increased total soluble solids (11.55 brix^0), average bulb weight increased whereas, higher yield was recorded with closest spacing. Naik and Hosamani (2003) [34] reported that the TSS content in onion was recorded maximum with wider spacing of 15 x 20 cm (9.09%) and decreased in other spacings. Yemane *et al*. (2012) reported that maximum rotten bulbs percent was observed at 10 cm intra-row spacing while, lowest percentage of rotten bulbs was seen at 5 cm intra-row spacing. Minimum sprouting (9.97%) occurred in small size bulbs compared to large size bulbs where sprouting was 13.62%. Shanthi and Balakrishnan (2013) reported in onion maximum T.S.S percentage (14.06%), total sugars (4.91%), ascorbic acid (10.03 mg/100g) and sulphur content (0.561 %) with higher planting density of 45 x 5 cm and all the parameters were decreased with low planting density. Srivastava *et al.* (2013) [51] reported that the closer spacing of 10 x 10 cm gave maximum sulphur content in both the seasons of 2011-12 and 2012-13 (0.749 and 0.788% respectively) and gradually decreased in other spacings.

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