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Studies on effect of different time of transplanting and spacing on growth, yield and quality of Knol-Khol (*Brassica oleracea var. gongylodes* L.) cv. Pusa Virat under middle Gujarat conditions

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Abstract
A field experiment was conducted during winter season of 2020-21at Horticultural Research Farm, Department of Horticulture, B. A. College of Agriculture, A.A.U., Anand "Study on effect of different time of transplanting and spacing on growth, yield and quality of Knol-Khol cv. Pusa Virat under middle Gujarat conditions". The experiment was conducted in RBD (Factorial) with three replications, considering different time of transplanting as first factor and different spacings as second factor. Factor-A Time of Transplanting (W_1-1st Week of November, W_2-3rd Week of November, W_3-1st Week of December), Factor-B Spacing (S_1-20 × 20 cm, S_2-30 × 20 cm, S_3-45 × 30 cm). The results obtained from the research experiment, it can be concluded that transplanting of knol-khol on 3rd week November and spacing of 20 x 20 cm was found ideal for getting higher yield under middle Gujarat conditions.

Keywords: transplanting, spacing, Knol-Khol *Brassica oleracea var. gongylodes* L.

Introduction
Knol-Khol (*Brassica oleracea var. gongylodes*) is a cool season crop. It is also known as kohlrabi, German turnip, cabbage turnip, Navalkol, Gunth Gobhi and Ganth gobhi. The name kohlrabi comes from the *German* word *Kohl* means "cabbage" plus *Rübe ~ rabi* (*Swiss German* variant) means "*turnip*" because the swollen stem resembles the letter. The bulb like swollen edible portion is stem known as knob, which arises from thickening of stem tissues above the cotyledon. Leaves are attached on this bulb like swollen structure. Knob is green or violet and generally round to flat round in shape. The fleshy turnip-like enlargement of the stem called knob develops entirely above the ground. This knob is harvested for human consumption as raw or cooked vegetable though in some parts, young leaves are also used.
This crop originated from wild species, *B. oleracea var. sylvestris* through mutation, human selection and adaptation along with other brassica vegetable like cabbage, cauliflower and broccoli.
Pusa Virat variety has dwarf plant type and semi spreading habit. Individual knob weight around 800 g and average yield is 23 tonnes/ha. Harvesting can be done from 50-60 days after transplanting. Both knobs and leaves are edible. It can withstand high frost and cold conditions
In recent years cultivation of Knol-Khol has gained momentum in India and has become increasingly popular with Indian growers for last couple of years. As Knol-Khol is exotic and temperate crop its commercial cultivation is restricted to only temperate region. In Gujarat it is very new crop and not having recommended spacing and week of transplanting under middle Gujarat condition, so the growers were following the spacing and date of transplanting of Solan, Himachal Pradesh condition only, this is the reason they were not getting good yield. Thus, the present research studies on the **"**Effect of different time of transplanting and spacing on growth, yield and quality of Knol-Khol (*Brassica oleracea var. gongylodes* L.) cv. Pusa Virat under middle Gujarat conditions" is taken with following objectives.

Objectives
1. To study the effect of different time of transplanting on growth, yield and quality of Knol-Khol
2. To study the effect of different spacing on growth, yield and quality of Knol-Khol

3. To study the interaction effect of different time of transplanting and spacing on growth, yield and quality of Knol-Khol

Materials and Methods

A field experiment was conducted during winter season of 2020-21 Horticultural Research Farm, Department of Horticulture, B. A. College of Agriculture, A.A.U., Anand "Study on effect of different time of transplanting and spacing on growth, yield and quality of Knol-Khol cv. Pusa Virat under middle Gujarat condition". The experiment was conducted in RBD (Factorial) with three replications, considering different time of transplanting as first factor and different spacings as second factor. Factor-A Time of Transplanting (W_1-1st Week of November W_2-3rd Week of November W_3-1st Week of December), Factor-B Spacing S_1-20 × 20 cm, S_2-30 × 20 cm S_3-45 × 30 cm). To raise the crop recommended package of practices was followed. The date of seed sowing in nursery bed was on 9th October, 24th October and 5th November 2020 and date of transplanting on 6th November, 19th November and 1st December. The data recorded for various parameters during the course of the investigation were statistically analysed as per the procedure described by Panse and Sukhatme (1985) [10].

Treatment combinations

Results and Discussion

Growth attributes

Plant height

Plant height was significantly influenced by different time of transplanting. 1st week of November transplanting (W_1) was superior (46.10 cm) over all other treatments which was found at par with the 3rd week of November transplanting (W_2) *i.e.* (45.44 cm).

Different spacing showed significant effect on plant height. The highest plant height (46.28 cm) was recorded under spacing of 30 x 20 cm (S_2) than other treatments.

The interaction between different time of transplanting and spacing showed non-significant effect on plant height.

The plant height was significantly increased on transplanting of 1st week of November (W_1) which was at par with transplanting on 3rd week of November. This might be due to conducive climatic conditions prevailed during the crop period while the plant height significantly reduced in 1st week of December transplanting (W_2), might be due to lower average minimum temperature during late transplanting. Similar results were reported by Singh *et al*. (2011), Kanase *et al*. (2017), Suthar *et al*. (2017) and Sighal *et al*. (2009).

Among the plant spacing's, 30 x 20 cm (S_2) exhibited maximum plant height. This might be due to more terminal increase in closer spaced plants than wider spaced plants, where lateral growth is more**.** Similar results were reported by Singh *et al*. (2010) [14].

Number of leaves per plant

Number of leaves significantly increased by different time of transplanting. Maximum number of leaves (14.24) recorded with transplanting on 3rd week of November.

Number of leaves significantly increased by different time of spacing. Maximum number of leaves (15.15) were recorded with spacing at 45 x 30 cm.

The interaction effect of different time of transplanting and spacing exhibited non-significant difference regarding number of leaves per plant of knol-khol.

It is apparent from the results that 3rd week of November transplanting had maximum number of leaves as compared to different time of transplanting. This might be due to optimum temperatures that prevailed during vegetative growth period which resulted in greater photosynthetic activities and higher mobilization of assimilates. Higher production of leaves per plant at ambient temperatures was also reported by Kumar *et al* (2006) [7], Suthar *et al.* and Singhal *et al.* (2005) in broccoli.

The closer spacing offered severe competition between the plants for nutrients, moisture, light and space due to which tallness in plants was observed. On the other hand, at wider spacing plant received more sunlight and more nutrients due to less number of plants which could increase the number of leaves per plant. The present results are in close agreement with the findings of Patil *et al.* (2003) [21] in cauliflower, Singh *et al.* (2004) in cauliflower, Khatun *et al.* (2011) [6], Moniruzzaman (2011) in cabbage, Solunke *et al.* (2011) [17] in broccoli, Dev (2012) [4] in broccoli.

Fresh weight of plant at knob initiation (g)

Fresh weight of plant at knob initiation stage was significantly influenced by different time of transplanting. Transplanting on 3rd week of November (W_2) was superior (100.82 g) over all other treatment.

The different spacing significantly affected the fresh weight of plant at knob initiation. Maximum fresh weight of plant at knob initiation stage (102.96 g) were recorded with spacing at 45 x 30 cm.

The interaction between different time of transplanting and spacing on fresh weight of plant at knob initiation stage was found non-significant.

Fresh weight of plant at harvesting stage (gm)

Fresh weight of plant at harvesting stage was significantly influenced by different time of transplanting. Transplanting on 3rd week of November (W_2) was found superior (619.98 g) over all treatment.

The different spacing were significantly affected the fresh weight of plant at knob harvesting. Maximum fresh weight of plant at harvesting stage (684.45 g) was recorded with spacing at 45 x 30 cm.

The interaction effect between different time of transplanting and spacing on fresh weight of plant at harvesting stage was found non-significant.

The significant differences among different plant spacing with respect to fresh weight of plant was due to good growth occurrence in wider plant spacing, more interception of light, less competition for moisture and nutrients that increases photosynthesis and accumulation of photosynthates in the plant. These finding are in accordance with the findings of Dev. H (2012) [4] in broccoli and Bhangre *et al.*, (2011) [2] in broccoli.

Leaf area (cm^2)

The different time of transplanting significantly influenced on leaf area (cm^2). The Maximum leaf area (333.03 cm^2) were recorded with transplanting on 3rd week of November.

Leaf area (cm^2) was significantly influenced by different spacing. Maximum leaf area (347.73 cm^2) were recorded with spacing at 45 x 30 cm.

The interaction effect between different time of transplanting

and spacing on fresh weight of plant at harvesting stage was found non-significant.

Days taken to 50% knob initiation

The number of days taken to 50% knob initiation stage significantly affected by different time of transplanting. Transplanting on 3rd week of November (w_2) was taken least days for 50% knob initiation.

The different spacing significantly affected on days taken for 50% knob initiation. Minimum days taken for 50% knob initiation (21.64) recorded with spacing at 45 x 30 cm (S_3) and at par with (21.99) spacing 30 x 20 cm (S_1).

The interaction between different time of transplanting and spacing showed non-significant effect on average days taken for 50% knob initiation.

Days to first knob harvesting

The number of days taken for first knob harvesting after transplanting significantly influenced different times of transplanting. Knol-khol transplanted on 3rd week of November (W_2) by took minimum days for first harvesting (53.35).

The interaction between different time of transplanting and spacing showed non-significant effect on average days taken for first knob harvesting of knol-khol.

Transplanting of knol-khol in treatment (W_2) planted at 3rd week of November taken least days for first knob harvesting (53.35). This might be due to the better meteorological conditions *i.e.* temperature, sunshine, day length and relative humidity during that period when compared with early transplanting of 1st week of November (W_1) and late planting 1st week of December (W_2). These moderate climatic conditions may allow more photosynthesis, more metabolites reflecting better vegetative growth which in turn resulted in early knob development. Similar results were obtained by Thapa *et al*. (2002) [18] in cauliflower, Saikia *et al*., (2010) [13], El-Magd (2013) and Nooprom *et al.*, (2013) [9] in broccoli.

Spacing of 30 cm x 45 cm required least days for first knob harvesting. This effect might to be due to wider spacing plant get more better light, better availability of space, aeration and soil moisture as well as better nutrient for the growth and development of the plant similar results obtained by Patil, B. N. *et al.*, (2003) [21]., Singal, P., *et al.*, (2009) and Khatun, K., (2011) [6] in broccoli

Days to final harvesting of knol-khol

The number of days taken for final harvesting after transplanting was significantly influenced different times of transplanting. Knol-khol transplanted on 3rd week of November (W_2) took minimum days for final harvesting (60.21).

The number of days taken for 1st knob harvesting after transplanting was significantly influenced by the different spacing. Minimum days taken for final harvesting (58.27) recorded with spacing at 45 x 30 cm.

The interaction between different time of transplanting and spacing showed non-significant effect on average days taken for final knob harvesting of knol-khol.

Knobs at wider spacings are ready for harvest earlier than those at closer spacings. At closer planting there might have been competition for moisture, space, nutrients and light. At wider plantings plant could assimilate food properly and therefore, knobs grew faster and were available for harvest earlier. These results of experiment are in close conformity with the findings of Oldenberg (1971) and Reimberr and Batz (1971) [12] who reported that at closer spacing knobs of knol-khol matured later than at wider spacing.

Table 1: Effect of different time of transplanting and spacing on growth attributes of knol-khol cv. Pusa Virat

Treatments	Plant height	Number of leaves	Fresh weight of plant (gm)	leaf area (cm^2)	Days taken for 50% knob initiation (days)	Days taken for 1st knob harvesting	Days to final harvesting
A. Time of transplanting (W)							
W_1 1st week of November	46.10	12.83	94.09	291.83	22.45	57.80	69.39
W_2 3rd week of November	45.44	14.24	100.82	333.03	20.64	53.35	60.21
W_3 1st week of December	42.67	12.93	95.06	268.79	23.50	59.20	71.15
S.Em. ±	0.65	0.33	1.54	6.53	0.35	1.48	2.03
CD (p=0.05)	1.96	1.01	4.36	19.05	1.06	4.44	6.11
B. Spacing (S)							
S_1 20 x 20 cm	44.24	11.70	91.53	253.53	22.95	61.86	75.28
S_2 30 x 20 cm	46.28	13.15	95.48	292.40	21.99	57.14	67.20
S_3 45 x 30 cm	43.70	15.15	102.96	347.73	21.64	51.36	58.27
S.Em. ±	0.65	0.33	1.54	6.35	0.21	1.48	2.03
CD (p=0.05)	1.96	1.01	4.36	19.05	1.06	4.44	6.11
W ×S Interaction							
S.Em. ±	1.13	0.58	2.67	11.00	0.61	2.50	3.53
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS
CV%	4.39	7.62	4.80	6.39	4.78	7.82	9.13

Yield Parameter

Knob length (cm)

The knob length was recorded maximum (8.13 cm) under transplanting on 3rd week of November (W_2).

Spacing showed significant effect on knob length. The highest knob length (8.78 cm) was recorded at a spacing of 45 x 30 cm.

Interaction effect of different time of transplanting and plant spacing was found non-significant with respect to knob length.

There was significant increase in knob length was observed in treatment (W_2) transplanting on 3rd week of November due to congenial temperatures which might have resulted in good vegetative growth of knob due to role of favourable temperature on growth and development of knob. Similar results were also reported by Hossian *et al.* (2011) in broccoli and Ara *et al*. (2009) [1] in cauliflower.

Maximum knob length was observed under Spacing of 30 cm

x 45 cm. This effect might be due to wider spacing plant get more better light, better availability of space, aeration and soil moisture as well as better nutrient for the growth and development of the plant similar results obtained by Patil, B. N. *et al.,* (2003) [21]., Singal, P., *et al.,* (2009) and Khatun, K., (2011) [6] in broccoli.

Knob diameter (cm)

The knob diameter was recorded maximum (8.46 cm) with transplanting on 3rd week of November (W_2).

Knob diameter was found significantly influenced by spacing showed significant effect on. The highest knob diameter (8.62 cm) was recorded at a spacing of 45 x 30 cm.

Interaction effect of different time of planting and plant spacing was found non-significant with respect to knob diameter of knol-khol.

The results showed that diameter of knob increased significantly in increasing levels of spacing (45 cm x 30 cm) and decreased at closer spacing (20 cm x 20 cm). This might be due to more number of plants in a given area causing severe competition for nutrients and sunlight which decreasing food assimilatory efficiency and thereby less reserve of food in knobs, due to this the weight and size of knob probably reduced. The results are in line with the findings of Nieuwhof (1969) [8].

Knob volume (cc)

The maximum volume of knob (320.05 cc) was recorded with transplanting on 3rd week of November (W_2).

Spacing showed significant effect on knob volume. The highest knob volume (340.48 cc) was recorded at a spacing of 45 x 30 cm.

Interaction effect of different time of transplanting and spacing was found non-significant with respect to knob volume (cc) of knol-khol.

Knob weight (g)

The knob weight was recorded maximum (349.62 g) with transplanting on 3rd week of November (W_2).

Spacing showed significant effect on knob weight. The highest knob weight (264.10 g) was recorded at a spacing of 45 x 30 cm.

Interaction effect of different time of transplanting and spacing was found non-significant with respect to knob weight (g) of knol-khol.

Yield per plot

The different time of transplanting showed their significant effects on knob yield per plot. Transplanting on 3rd week of November gave the highest knob yield per plot (48.01 kg).

Spacing showed significant effects on knob yield per plot. Spacing of 20 x 20 cm (S_1) was turned superior over other treatments by producing the highest knob yield per plot.

Interaction effect on different time of transplanting and spacing showed non-significant difference with respect to knob yield per plot.

The significant differences among different plant spacing with respect to fresh weight of knob was due to good growth occurrence in wider plant spacing, more interception of light, less competition for moisture and nutrients which increases photosynthesis and accumulation of photosynthates in the main head. These finding are in accordance with the findings of Dev. H (2012) [4] Bhangre *et al.,* (2011) [2] in broccoli.

Yield per hectare

The different time of transplanting showed their significant effects on knob yield per hectare. Transplanting on 3rd week of November gave highest knob yield per hectare (52.81 t).

The different spacing showed their significant effects on knob yield per hectare. Spacing of 20 x 20 cm (S_1) was turned superior over others treatments by producing the highest knob yield per hectare (61.20 t).

Interaction effect on different time of transplanting and spacing showed non-significant difference with respect to knob yield per hectare (t).

Yield per plot (kg) and per hectare (t) was significantly exerted by different plant spacing. The vegetative and reproductive phase of plant growth was mainly influenced by day length, hours of bright sunshine received and suitable temperature prevailing during growth and head formation period. The distance planted plant received comparatively low temperature during vegetative growth which produced early and bigger sized knob. The highest total yield might to be due to its vigour plants with denser leaves which intercept more sunlight. These results are in conformity with the finding of Whitwell *et al.* (1981) [23] in Brussels sprout, Korus (2010) for kale and Uddain *et al.* (2012) [19] for knolkhol.

By increasing the spacing, total yield of knol-khol decreased significantly. It was perhaps due to the reduction in number of knobs harvested in given area as the spacing increased. In other word, increase in yields of knol-khol at closer spacing was due to more number of plants accommodated in a given area. Wide spacing leads to low yields due to low plant population per unit area, but knob quality was improved as size of the fruit was bigger and unit knob weight was higher. These results are in close conformity with the findings of Patil *et al.* (2003) [21] and Rai *et al.* (2003) [11] in knol-khol and Kumar and Rawat (2002), Singh *et al.* (2004) and in cabbage and Prasad *et al.* (2010) [22], Khatun *et al.* (2011) [6], Dev (2012) [4] in broccoli.

Table 2: Effect of different time of transplanting and spacing on growth attributes of knol-khol cv. Pusa Virat

Treatments	Knob length (cm)	Knob diameter (cm)	Knob volume (cc)	Knob weight (gm)	Knob yield per plot (kg)	Knob yield per hectare (t)
A. Time of transplanting (W)						
W_1 1st week of November	7.45	7.12	283.11	312.71	43.26	47.52
W_2 3rd week of November	8.41	8.46	320.05	349.62	48.01	52.81
W_3 1st week of December	7.18	7.00	271.53	296.90	41.12	45.15
S.Em. ±	0.17	0.19	9.89	7.19	0.90	0.95
CD (p=0.05)	0.52	0.57	29.67	21.58	2.72	2.86
B. Spacing (S)						
S_1 20 x 20 cm	6.70	6.54	235.75	264.10	58.22	61.20
S_2 30 x 20 cm	7.75	7.42	298.46	317.09	40.33	49.64

S_3 45 x 30 cm	8.78	8.62	340.48	378.05	32.57	34.34
S.Em. ±	0.17	0.19	9.89	7.19	0.90	0.95
CD (p=0.05)	1.96	0.57	29.67	21.58	2.72	2.80
W ×S Interaction						
S.Em. ±	0.30	0.33	17.14	12.96	0.55	1.65
CD (p=0.05)	NS	NS	NS	NS	NS	NS
CV%	6.90	7.61	10.18	6.75	6.17	5.90

Quality Attribute

Knob dry matter

The effect of different time of transplanting was found non-significant with respect to knob dry matter (%) of knol-khol.

The different spacing significantly affected by the knob dry matter (%). Maximum dry matter (15.12%) were recorded with spacing at 20 x 20 cm.

The interaction effect of different time of transplanting and spacing was found non-significant with respect to knob dry matter (%) of knol-khol.

Ascorbic acid (mg/100 gm)

The effect of different time of transplanting, different spacing and also their interaction was found non-significant with respect to ascorbic acid (mg/100 gm) of knol-khol.

TSS (^{o}Brix)

The effect of different time of transplanting, different spacing and also their interaction was found non-significant with respect to TSS (^{0}Brix) of knol-khol.

Table 3: Effect of different time of transplanting and spacing on quality of knol-khol cv. Pusa Virat

Treatments	Dry matter (%)	Ascorbic acid (mg/100gm)	TSS (^{0}Brix)
A. Time of transplanting (W)			
W_1 1st week of November	14.41	36.08	6.9
W_2 3rd week of November	14.23	36.25	6.7
W_3 1st week of December	14.20	36.44	6.9
S.Em. ±	0.11	0.24	0.13
CD (p=0.05)	NS	NS	NS
B. Spacing (S)			
S_1 20 x 20 cm	15.12	35.77	6.8
S_2 30 x 20 cm	14.04	36.45	7.0
S_3 45 x 30 cm	13.68	36.54	6.7
S.Em. ±	0.11	0.24	0.13
CD (p=0.05)	0.33	NS	NS
W ×S Interaction			
S.Em. ±	0.19	0.42	0.23
CD (p=0.05)	NS	NS	NS
CV%	2.37	2.01	2.37

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