The Pharma Innovation Journal 2021; 10(8): 1482-1485

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(8): 1482-1485

www.thepharmajournal.com
Received: 10-05-2021
Accepted: 29-06-2021

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Determining the combined effect of varieties and spacing on growth, yield and quality of Knolkhol (*Brassica oleracea* var. *gongylodes* L.)

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Abstract
The field experiments were carried out at Horticulture Research Farm-I, Babasaheb Bhimrao Ambedkar University, Lucknow (U.P.) during Rabi season of 2018-19 and 2019-20 to study the combined effect of varieties and spacing on growth, yield and quality of Knolkhol (*Brassica oleracea* var. *gongylodes* L.). The treatments were designed in a factorial randomized design with three replications, four varieties: V_1 (Pusa Virat), V_2 (White Vienna), V_3 (Early White Vienna) and V_4 (Palam Tender Knob) with four spacings: S_1 (30 x 30 cm^2), S_2 (45 x 30 cm^2), S_3 (45 x 45 cm^2) and S_4 (60 x 45 cm^2) were evaluated. The White Vienna with spacing 60 x 45 cm^2 showed maximum plant height (31.92 cm), number of leaves per plant (19.94), length of leaf (25.75 cm), width of leaf (27.63 cm) and plant spread (31.94 cm), knob weight per plant (238.25 g), diameter of knob (6.36 cm) and volume of knob (119.52 cc). White Vienna with spacing 30 x 30 cm^2 exhibited that the maximum yield per plot (7.07 kg) and yield (218.06 q ha^{-1}). The maximum TSS (3.90 ^{0}Brix) was observed in Early White Vienna with spacing 45 x 45 cm^2, maximum vitamin C (39.08 mg/100g) was noticed in Early White Vienna with spacing 30 x 30 cm^2) in Knolkhol.

Keywords: Knolkhol, combined effect, varieties, spacing, growth, yield, quality

Introduction
Knolkhol (*Brassica oleracea* var. *gongylodes* L.) is a winter season crop under cole group and belongs to Brassicaceae family that originated in Mediterranean coastal countries. It is also known as kohlrabi and Ganth gobhi. It is widely grown in Jammu & Kashmir, West Bengal and to a lesser extent in Maharashtra, Assam, Uttar Pradesh and Punjab as a rare exotic vegetable. Knolkhol has a bulb-like swollen edible portion called knob. The stem's fleshy turnip-like expansion develops completely above ground. The knob is harvested for human use as a raw or cooked vegetable, while young leaves are also utilised in some areas (Chadha, 2019) [4]. Kohlrabi taste feels like broccoli or cabbage, but it's gentler and sweeter. The knobs have a crunchy texture and a rich flavour. One hundred gram of comestible portion of knolkhol contains 92.7 g moisture, 1.1 g protein, 0.2 g fat, 1.5 g fibre, 3.8 g carbohydrates, 25 cal. energy, 20 mg calcium, 18 mg magnesium, 10 mg oxalic acid, 35 mg phosphorus, 0.4 mg iron, 0.12 mg sodium, 37 mg potassium, 0.09 mg copper, 143 mg Sulphur, 36 I.U. vitamin A, 0.12 mg riboflavin, 0.5 mg nicotinic acid, 0.05mg thiamine and 85 mg vitamin C (Bose, 2001) [3]. It contains sulforaphane, a cancer-fighting compound. All components of the knolkhol plant have been reported to have enormous therapeutic powers. Asthma, cancer, high cholesterol, heart disorders, indigestion, muscle and nerve functioning, colon cancer, skin problems and weight loss are among the medicinal characteristics of the crop. Knolkhol is mostly cultivated as a winter vegetable crop that thrives best in cool and moist climates Seeds germinate successfully at temperatures ranging from 15 to 30 °C. The ideal temperature for its growth is between 15 and 25 °C, depending on the cultivar. It may be cultivated in a wide range of soil. However, uniform growth is encouraged by good soil conditions and fertility. The ideal pH range of soil is 6.0-7.0 (Choudhary, 2015) [5]. In the growth and development of a crop, varieties are important. Only a few cultivars of Knolkhol, such as Pusa Virat, White Vienna, Early White Vienna and Palam Tender Knob were developed for the cold winters of North India. Maintaining an appropriate plant population per unit area is essential for knolkhol better growth and higher production. Optimum spacing ensures judicious use of natural resources and makes the intercultural operation easier as suggested by (Hasan *et al.*, 2017) [6]. The spacing of crop varied according to climatic condition, soil fertility and cultivar adaption to

particular region. (Bairwa *et al.*, 2017) [2] reported that under the wider spacing, the plant was more vigorous in terms of growth of plants, which may be due to less competition for light, nutrients and moisture as compared to closer spacing (Kaur *et al.*, 2020) [8]. Hence, in the present study efforts have been made to understand the combined effect of varieties and spacing on growth, yield and quality of Knolkhol under Lucknow conditions.

Materials and Methods

The experiments were conducted during winter season of 2018-19 and 2019-20 at Horticulture Research Farm-I, Department of Horticulture, Babasaheb Bhimrao Ambedkar University, Lucknow, (U.P.), India. The experimental site is situated at 80° 92′'East longitude and 26° 76′' North latitude and 123 meter above MSL (Mean Sea Level). The climate of Lucknow is characterized by sub-tropical with hot, dry summer and cool winters. The soil of experimental field is sandy loam and slightly alkaline in nature with soil pH 8.2, 85.46 kg ha^{-1} available nitrogen, 16.62 kg ha^{-1} and 142.07 kg ha^{-1} available potash. In a factorial randomized block design with three replications, four varieties: V_1 (Pusa Virat), V_2 (White Vienna), V_3 (Early White Vienna) and V_4 (Palam Tender Knob) with four spacings: S_1 (30 x 30 cm^2), S_2 (45 x 30 cm^2), S_3 (45 x 45 cm^2) and S_4 (60 x 45 cm^2) were evaluated. The application of recommended dose of fertilizer (180: 120: 100 kg/ha NPK) through Urea, diammonium phosphate and muriate of potash. To raise the crop, appropriate management practices have been used. Randomly five plants were selected in each plot and data recorded on the following growth, yield and quality parameters *viz*.- plant height, number of leaves per plant, leaf length, leaf width, plant spread, weight of knob, diameter of knob, volume of knob, yield/plot, yield/ha, total soluble solids (°Brix) were determined by using hand refractometer and vitamin C (mg/100g) by titration against 2,6 dichlorophenolindophenol dye (Anonymous, 1995) [1], reducing sugar (%), non-reducing sugar (%) and total sugars (%) were determined by titrating the sample against Fehling solution using methylene blue as an indicator. The observations on growth, yield and quality parameters were statistically analysis of the data obtained in different set of experiments was calculated following the standard procedure as stated by (Panse and Sukhatme, 1985) [15]. The data were analysed and are presented at the 5% level of significance.

Results and Discussion

Combined effect of varieties and spacing on growth parameters

The combined effect of different varieties and spacing had significant influence on growth parameters during both the years of experimentation. The data (Table 1) revealed that the maximum plant height (31.92 cm), number of leaves per plant (19.94), length of leaf (25.75 cm), width of leaf (27.63 cm) and plant spread (31.94 cm) were recorded at harvest in White Vienna with spacing 60 x45 cm^2. However, the minimum plant height (24.88 cm), number of leaves per plant (16.11), length of leaf (19.56 cm), width of leaf (21.95 cm) and plant spread (26.06 cm) were recorded at harvest in Pusa Virat with spacing 30 x30 cm^2. It may be due to genetic diversity across cultivars in terms of growth characteristics, as well as variations in agro - climatic conditions. The close spacing induced intense competition amongst the plants for nutrients, moisture, light and space, resulting in plant tallness. Plants with wider spacing, on the other hand, received more sunlight and nutrients due to fewer plants, that might enhance the vegetative growth of plant. These data are compatible with those of (Ngullie and Biswas, 2014) [14], (Singh *et al.*, 2007) [20] in cabbage, (Ullah *et al.*, 2013) [24] in cabbage, (Singh *et al.*, 2014) [21] in broccoli, (Singh, 2015) [19] in cabbage and (Kumar *et al.*, 2021) [12] in broccoli.

Table 1: Combined effect of varieties and spacing on growth parameters of knolkhol at harvest (mean of 2 years)

Treatments	Plant height (cm)	Number of leaves per plant	Length of leaf (cm)	Width of leaf (cm)	Plant spread (cm)
V_1S_1	24.88	16.11	19.56	21.95	26.06
V_1S_2	27.73	16.47	22.09	22.74	27.87
V_1S_3	26.48	17.13	20.69	23.18	29.47
V_1S_4	30.34	18.68	24.69	23.92	30.17
V_2S_1	28.93	18.42	23.66	26.47	26.79
V_2S_2	29.62	17.67	24.12	25.15	28.65
V_2S_3	28.64	19.54	24.71	26.56	29.19
V_2S_4	31.92	19.94	25.75	27.63	31.94
V_3S_1	28.19	16.73	23.90	23.84	29.48
V_3S_2	28.46	17.13	22.63	24.35	28.92
V_3S_3	29.53	17.78	24.15	26.31	30.02
V_3S_4	31.15	18.59	25.06	27.25	30.55
V_4S_1	26.91	17.08	23.21	25.58	28.90
V_4S_2	26.73	19.08	23.85	26.15	28.93
V_4S_3	30.03	18.23	24.13	26.20	30.69
V_4S_4	31.49	18.11	25.30	26.94	31.16
S.Em±	0.36	0.32	0.38	0.50	0.38
CD (P=0.05)	1.02	0.90	1.08	1.40	1.06

Combined effect of varieties and spacing on yield parameters

Table 2 showed that different varieties and spacing had significant influence on yield and yielding attributes of knolkhol during first and second year. The maximum knob weight per plant (238.25 g), diameter of knob (6.36 cm) and volume of knob (119.52 cc) were recorded in White Vienna with spacing 60 x45 cm^2 whereas, the minimum knob weight per plant (172.96 g), diameter of knob (3.91 cm) and volume of knob (97.74 cc) were recorded in Pusa Virat with spacing 30 x30 cm^2. These might be due to long distance spacing was exposed to avoided any setback to the growth, rather it provided congenial atmosphere among the different growing environment. These results are in conformity with the finding

of (Korus, 2010) [9] in kale. White Vienna with spacing 30 x 30 cm^2 showed that the maximum yield per plot (7.07 kg) and yield (218.06 q ha^{-1}). It was found statistically at par with Early White Vienna with 30 x30 cm^2 spacing and Palam Tender Knob with 30 x30 cm^2 spacing but significantly superior over other treatments. However, the minimum yield per plot (2.63 kg) and yield (81.17 q ha^{-1}) were recorded in Pusa Virat with spacing 60 x45 cm^2. 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 knob formation period. The significant yield different among the varieties may be due to genetical parameter. Each individual genotype or variety has its own specific characteristics which are inheritant. Accordingly, variation in yield parameters may be attributed to the genetic difference of varieties leads to better yield. These results are in aggregate with those obtained by (Singh *et al.*, 2010) [18] in cabbage, (Naik and Gupta, 2010) [13] in kale, (Prasad *et al.*, 2010) [16] in broccoli, (Ullah *et al.*, 2013) [24] in cabbage and (Joshi *et al.*, 2018) [7] in hybrid cauliflower.

Table 2: Combined effect of varieties and spacing on yield and yielding attributes of knolkhol (mean of 2 years)

Treatments	Weight of knob (g)	Diameter of knob (cm)	Volume of knob (cc)	Yield (kg/plot)	Yield (q/ha)
V_1S_1	172.96	3.91	97.74	6.30	194.35
V_1S_2	180.85	4.07	99.98	4.34	133.95
V_1S_3	195.48	5.11	101.80	3.12	96.36
V_1S_4	219.59	5.24	108.45	2.63	81.17
V_2S_1	205.29	4.58	102.14	7.07	218.06
V_2S_2	221.40	4.98	105.91	5.21	163.89
V_2S_3	224.30	5.49	110.33	3.61	111.27
V_2S_4	238.25	6.36	119.52	2.82	87.04
V_3S_1	192.40	4.33	107.69	6.92	213.58
V_3S_2	209.73	4.91	105.35	5.09	157.10
V_3S_3	212.39	5.29	111.56	3.53	108.95
V_3S_4	228.20	6.03	116.46	2.74	84.41
V_4S_1	196.40	4.55	107.34	6.87	211.96
V_4S_2	192.87	4.92	112.38	4.97	150.15
V_4S_3	219.67	5.58	116.60	3.37	103.86
V_4S_4	233.59	6.04	115.66	2.84	87.50
S.Em±	6.84	0.14	2.78	0.16	4.80
CD (P=0.05)	19.36	0.40	7.84	0.44	13.58

Combined effect of varieties and spacing on quality parameters

The combined effect of different varieties and spacing on quality parameters of Knolkhol was significantly influenced during both the years of experimentation. The data (Table 3) revealed that the maximum TSS (3.90 °Brix) was recorded in Early White Vienna with spacing 45 x 45 cm^2 followed by Palam Tender Knob with spacing 45 x 30 cm^2 (3.73 °Brix) while, the minimum TSS (2.22 °Brix) was recorded in White Vienna with spacing 45 x 45 cm^2. The maximum vitamin C (39.08 mg/100g) was recorded in Early White Vienna with spacing 30 x 30 cm^2. It was found statistically at par with White Vienna with spacing 45 x 30 cm^2, White Vienna with spacing 45 x 45 cm^2 and Early White Vienna with spacing 45 x 30 cm^2 but significantly superior to rest of the treatments. However, the minimum vitamin C (32.74 mg/100g) was noticed in Pusa Virat with spacing 30 x 30 cm^2. These findings were in close conformity with those of (Singhal *et al.*, 2009) [22]. The maximum reducing sugar (2.39%) was recorded in Palam Tender knob with spacing 45 x 45 cm^2 followed by White Vienna with spacing 60 x 45 cm^2 while, the minimum reducing sugar (1.5%) was recorded in Pusa Virat with spacing 30 x 30 cm^2. The maximum non-reducing sugar (1.05%) was recorded in White Vienna with spacing 45 x 45 cm^2 however, the minimum non-reducing sugar (0.65%) was recorded in Pusa Virat with spacing 30 x 30 cm^2. The maximum total sugar (3.18%) was recorded in Palam Tender Knob with spacing 45 x 45 cm^2. However, the minimum total sugar (2.28%) was noticed in Pusa Virat with spacing 30 x 30 cm^2. When the distance between plants increased, the quality related parameters were also increased. Similar findings observed by (Kumar and Rawat, 2002) [10] in cabbage, (Singh *et al.*, 2010) [18] in cabbage, (Scuderi *et al.*, 2013) [17] in chinese cabbage, (Suthar *et al.*, 2017) [23] in broccoli, (Kumar *et al.*, 2021) [11] in broccoli.

Table 3: Combined effect of varieties and spacing on quality parameters of Knolkhol (mean of 2 years)

Treatments	Total soluble solids (°Brix)	Vitamin C (mg/100g)	Reducing sugar (%)	Non-reducing sugar (%)	Total sugars (%)
V_1S_1	3.12	32.74	1.52	0.65	2.28
V_1S_2	2.82	33.26	1.65	0.77	2.41
V_1S_3	2.99	34.83	1.90	0.79	2.59
V_1S_4	3.01	35.01	2.14	0.76	2.90
V_2S_1	3.29	35.82	1.97	0.89	2.86
V_2S_2	3.11	38.45	2.13	0.90	3.03
V_2S_3	2.22	37.41	1.87	1.05	2.86
V_2S_4	3.19	37.10	2.27	0.68	2.95
V_3S_1	3.17	39.08	1.96	0.76	2.75
V_3S_2	2.96	38.24	2.14	0.88	3.03
V_3S_3	3.90	34.22	2.17	0.92	3.05

V_3S_4	2.81	33.98	2.22	0.84	3.06
V_4S_1	3.51	35.17	2.07	0.89	2.99
V_4S_2	3.73	36.91	2.18	0.80	3.02
V_4S_3	3.41	37.76	2.39	0.84	3.18
V_4S_4	3.49	37.35	2.15	0.90	3.10
S.Em±	0.14	0.34	0.06	0.02	0.08
CD (P=0.05)	0.42	0.96	0.16	0.06	0.20

Conclusion

The combined effect of varieties and spacing on the growth, yield and quality attributes of Knolkhol was significant. The White Vienna with wider spacing 60 x 45 cm^2 proved to be most effective in increasing the vegetative growth attributes. White Vienna with spacing 30 x 30 cm^2 showed that the maximum yield per plot and yield per ha of Knolkhol. In quality traits like total soluble solids, reducing sugar and total sugars were found in Palam Tender Knob with spacing 60 x 45 cm^2 except non-reducing sugar, chlorophyll content and vitamin-C. Hence, White Vienna with spacing 30 x 30 cm^2 may be recommended for commercial cultivation under Lucknow conditions.

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