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Growth, yield and quality of knol-khol (*Brassica oleracea* var. gongylodes) as affected by fertilizer management

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ABSTRACT

A field experiment was conducted during rabi (winter) season of 2016-2017 at Horticultural Research Center, Department of Horticulture, Chauras Campus, HNB Garhwal University, of Uttarakhand to assess the effectiveness of combined dose of organic manure and fertilizer on knol-khol (*Brassica oleracea* var. gongylodes) vegetable crop. The study involved twenty treatments *viz.*, no fertilizer control (T0), recommended doses of fertilizers (RDF) 100% (T1), RDF 50% (T2), *Azospirillum* (T3), *Azotobacter* (T4), Neem cake (T5), Chicken manure (T6), RDF 75% + *Azospirillum* (T7), RDF 75% + *Azotobacter* (T8), RDF 75% + neem cake (T9), RDF 75% + chicken manure (T10), RDF 50% + *Azospirillum* (T11), RDF 50% + *Azotobacter* (T12), RDF 50% + neem cake (T13), RDF 50% + chicken manure (T14), *Azospirillum* + *Azotobacter* (T15), *Azospirillum* + neem cake (T16), *Azospirillum* + chicken manure (T17), *Azotobacter* + neem cake (T18), *Azotobacter* + chicken manure (T19), and neem cake + chicken manure (T20). The results showed that the treatment T7 (RDF 75% + *Azospirillum*) is more efficient over other treatments in terms of yield. The highest yield was found (61.83% over control) in treatment T7 (RDF 75% + *Azospirillum*) as compared to control (T0). Different fertilizer-use efficiencies were significantly improved with the application of organic, inorganic and bio-fertilizer over control as well as chemical fertilizer alone. The treatment T7 (RDF 75% + *Azospirillum*) showed maximum nutrient use efficiency and the minimum value was recorded in T2 (RDF 50%) > T1 (RDF 100%) > T17 (*Azospirillum* + chicken manure) > T15 (*Azospirillum* + *Azotobacter*) > T5 (neem cake) and T0 (control). Study concluded that the combination of organic manure and bio-fertilizer improved the growth and yield of knol-khol (*Brassica oleracea* var. gongylodes) plant. Therefore, the application of organic manure and bio-fertilizers are recommended for knol-khol production.

Keywords: Bio fertilizer, organic manures, growth, yield, *Brassica oleracea* var. gongylodes

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1 Introduction

Cole crops are one of the major vegetable groups in the kingdom. Cole crops including cauliflower, cabbage, knol-khol, etc., have economic importance and medicinal value for human health (Kumar et al., 2017). Knol-Khol (*Brassica oleracea* var. gongylodes) is a rabi season cole crop belongs to family Brassicaceae which is originated from the coastal countries of Mediterranean region. In India, the cultivation of knol-khol is popular in Kashmir, West Bengal, Maharashtra, Assam, Uttar Pradesh, Punjab, Odisha and some parts of South India (Mishra et al., 2014). Basically edible part of knol-khol is knob, which is form swelling of the stem tissue above the cotyledons. The crop has tremendous medicinal properties like, acidosis, asthma, cancer, cholesterol level, heart problems, indigestion, muscle and nerve functions, prostate and colon cancer, skin problems, weight loss etc (Chauhan et al., 2016). The main component of sustainable agriculture is the utilization of all the three major nutrients sources like, inorganic, organic and biofertilizers. These three components have various advantages such as, they enhance the rapid availability of various essential nutrients, improves the soil's physical, chemical, and biological properties along with conserving the moisture-holding capacity, fixed the atmospheric nitrogen and transformed the unavailable to available forms of nutrients (Chaudhary and Singh, 2018; Singh et al., 2019).

Nitrogen supports the transformation of carbohydrates into proteins and promotes the formation of protoplasm in cells. A sufficient supply of mineral nitrogen is associated with good vegetative growth and improves the capacity of plants to use all the available inputs from the soil which leads to higher productivity (Kumar et al., 2012; Chaudhary and Singh, 2018; Singh et al., 2019). Phosphorus is one of the key components of nucleic acid, phospholipids, and several other enzymes. It also plays a vital role for the transfer of energy within the plant body system and has a very efficient effect on early root growth and development (Chaudhary and Singh, 2018; Malhotra et al., 2018). While, potassium play their role in plant vigour and different disease resistance capacity to plants and acts as a activator of numerous enzymes like, pyruvic kinase, cytoplasmic enzymes etc. The bio-fertilizers are organic in origin and thus are absolutely safe for soil and also the human point of view. It is responsible for the pervasive effect on metabolic events of the plant system (Ashley et al., 2005; Wang et al., 2013).

The interactive advantages of combining inorganic and organic sources of nutrient generally provide superior status to use of each component separately. The judicious application of organic and inorganic fertilizers have maintained long term soil fertility and sustained a higher level of productivity.

Therefore, the present study is aimed to assessment of comparative effectiveness of different organic manure and bio-fertilizer for a sustainable agricultural crop production. The hypothesized of the study is the selection of the organic manure and their effectiveness for sustainable agriculture.

2 Materials and Methods

2.1 Experimental site and design

Srinagar (Garhwal) is located in the heart of Alaknanda valley (30°13′0″N, 78°47′30″E) at an elevation of 540 m above MSL), a semi-arid, subtropical climate with dry summer and rigorous winters with occasional dense fog in the morning hours from mid December to mid February. The experiment was conducted at Horticultural Research Centre, Department of Horticulture, H.N.B Garhwal University, Srinagar (Garhwal), Uttarakhand during winter season, 2016-2017.

The experiment was laid out in a randomized complete block design (RCBD) with three replications. The entire experimental field was divided into three blocks and each block consisted of 21 plots of equal size. The seed of knol-khol cv. White Vienna was collected from IARI New Delhi, the nursery was raised on flat beds system. The four week old seedling of knol-khol cv. White Vienna was transplanted according to as experimental design in flat beds during the mid November, 2016-2017. Each plot measured 3.24 m^2 areas with the spacing of 45 cm $\times$ 30 cm spacing.

Four weeks old seedlings of knol-khol cv. White Vienna was inoculated with *Azospirillum* and *Azotobacter*. Full dose (recommended) of neem cake and chicken manure were applied 15 days before transplanting of seedling. Full quantity of phosphorus, potassium and half dose of nitrogen applied before transplanting of seedlings, while the remaining half dose of nitrogen was used in split doses at 20 and 35 days after transplanting (DAT) as broadcasting. All the essential intercultural operations and plant protection measures were followed as per recommendation for the crops.

2.2 Application of fertilizers

The experiment materials consist of organic, inorganic manures, bio-fertilizer and their combinations. The treatments combinations are given in Table 1.

2.3 Plant sampling

The plant sample was collected early morning from each plot and after first sampling plant was tagged for the next sampling. The sample was kept in polythene pouches for avoiding water losses. Triplicate of the sample was taken from each plot.

Table 1. Description of treatments

Treatments	Description
T0	Control
T1	RDF 100%
T2	RDF 50%
T3	*Azospirillum*
T4	*Azotobacter*
T5	Neem (*Azadirachta indica*) cake
T6	Chicken manure
T7	RDF 75% + *Azospirillum*
T8	RDF 75% + *Azotobacter*
T9	RDF 75% + neem cake
T10	RDF 75% + chicken manure
T11	RDF 50% + *Azospirillum*
T12	RDF 50% + *Azotobacter*
T13	RDF 50% + neem cake
T14	RDF 50% + chicken manure
T15	*Azospirillum* + *Azotobacter*
T16	*Azospirillum* + neem cake
T17	*Azospirillum* + chicken manure
T18	*Azotobacter* + neem cake
T19	*Azotobacter* + chicken manure
T20	Neem cake + chicken manure

2.4 Plant growth and biomass

Plant growth and biomass were analyzed by standard method. The number of leaves counted after the interval of days. Plant height and length of knob was measured with the help of scale meter. Dry and fresh weight of the plant part was determined by using hot air oven and weighing balance.

2.5 Yield and quality characteristics

Yield characteristic was determined by the weight of total yield (kg plot^{-1}) and total yield (q ha^{-1}). Quality characteristic including total soluble solid (°Brix) and vitamin C (mg 100g^{-1}) was determined by the standard method.

2.6 Statistical analysis

The obtained data were analyzed using analysis of PCA (Principle component analysis) by origin Pro 2019 software. Bi-plots score of PCA (PC1 and PC2) shows the correlation between different treatments responses on knol-khol (*Brassica oleracea* var. gongylodes) vegetable.

3 Results

3.1 Plant height and leaf number

The obtained result from the study shows that, the maximum plant height was recorded (40.71%) in treatment (T7) (75% RDF + *Azospirillum*) at 30 DAT and minimum in treatment T2 (0.005%) as compared to control treatment (T0) at the end of harvested plant maximum plant height was recorded in T8 (75% RDF + *Azotobacter*) (36.81%), whereas the minimum in T2 (0.0007%) as compared to control T0 (Fig. 1). Number of leaf was also significantly variate with treatment (Fig. 1). The maximum number of leaves was recorded in treatment T4 (*Azotobacter*) (35.63%) and minimum in treatment T2 (0.0014%) at 30 DAT as compared to control T0. On the other hand, maximum number of leaves of harvested plant was found in treatment in T11 (34.70%) and minimum in T2 (0.0007%) as compared to control T0.

3.2 Knob initiation and knob harvest

In the present study, the minimum days taken to knob initiation was recorded in treatment T7 (75% RDF + *Azospirillum*), which was found to be significantly lower over other treatments, whereas the maximum days taken to knob initiation was noticed in treatment T0. While, minimum day taken to first knob harvest was also recorded in treatment T7 (75% RDF + *Azospirillum*) and maximum days taken to first knob harvest was noticed in treatment T0. Days taken to complete harvesting of knob in treatment T17 (*Azospirillum* + chicken manure) at 110 d while treatment T6 (chicken manure) taken 72 d for knob harvesting time (Fig. 2).

3.3 Knob size

Maximum volume of knob was recorded in treatment T7 (75% RDF + *Azospirillum*) (75.38%), while minimum value was noted in treatment T2 (0.006%) as compared to control plant (Fig. 3). Maximum knob diameter was recorded in treatment T8 (75% RDF + azatobacter) (42.02%) and minimum in treatment T2 (0.002%) as compared to control T0. Maximum increment of knob length was recorded in treatment T7 (42.85%) and minimum in treatment T2 (0.002%) as compared to treatment T0.

3.4 Fresh and dry weight of knob

The maximum increament of fresh weight of knob (77.11%) was recorded in treatment T7 (75% RDF + *Azospirillum*), while minimum in treatment T2 (0.006%) as compared to control plant. Trends of knob fresh weight was found higher in treatments T7 (77.11%) >T8 (75.68%) > T10 (72.47%) >T18 (71.99%) >T14 (71.81%) >T9 (70.92%)> T3 (70.36%) while treatments T6 (68.90%)> T11 (68.87%)>T19 (67.62%) >T16 (65.33%) > T13 (64.41%) > T4 (64.37%) >shows moderate increment and treatmentsT20 (63.66%) > T12 (63.25%) > T5 (59.55%)> T15 (56.58%) T1 (48.57%) >T17 (25.38%) shows lowest value as compared to control (Fig. 4). Dry weight of knob was higher

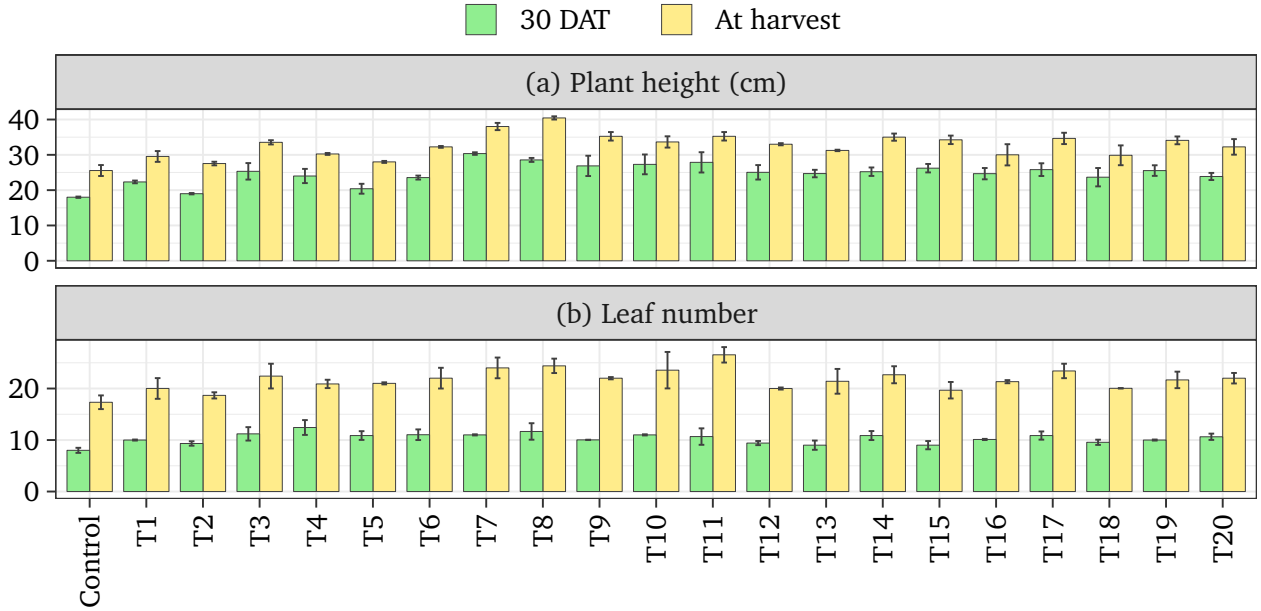

Figure 1. Effect of fertilizer management on (a) plant height, and (b) leaf number of knol-khol (*Brassica oleracea* var. gongylodes). T0 = Control (no fertilizer), T1 = RDF 100%, T2 = RDF 50%, T3 = *Azospirillum*, T4 = *Azotobacter*, T5 = Neem cake, T6 = Chicken manure, T7 = RDF 75% + *Azospirillum*, T8 = RDF 75% + *Azotobacter*, T9 = RDF 75% + neem cake, T10 = RDF 75% + chicken manure, T11 = RDF 50% + *Azospirillum*, T12 = RDF 50% + *Azotobacter* , T13 = RDF 50% + neem cake, T14 = RDF 50% + chicken manure, T15 = *Azospirillum* + *Azotobacter*, T16 = *Azospirillum* + neem cake, T17 = *Azospirillum* + chicken manure, T18 = *Azotobacter* + neem cake, T19 = *Azotobacter* + chicken manure, T20 = Neem cake + chicken manure

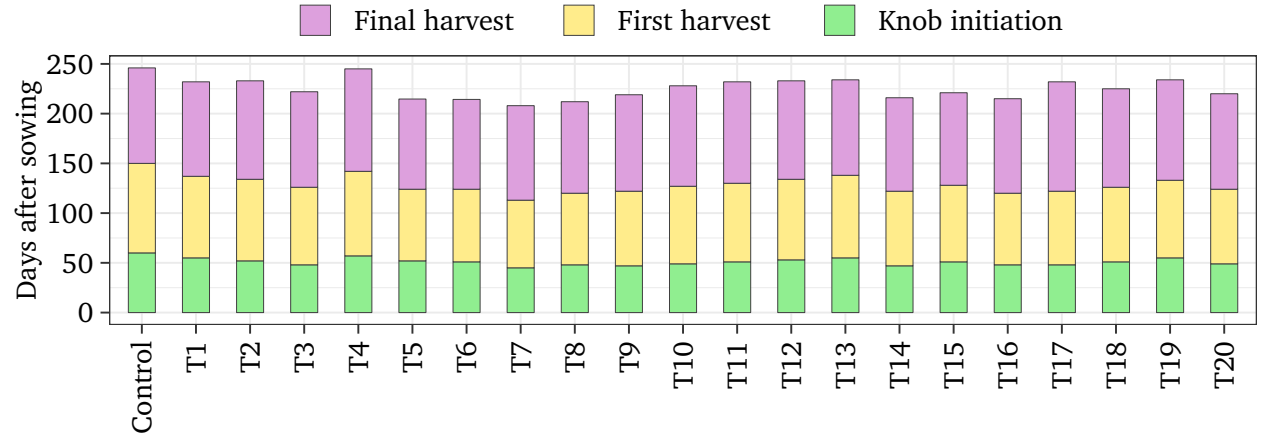

Figure 2. Effect of fertilizer management on knob initiation and harvesting time of knol-khol (*Brassica oleracea* var. gongylodes). T0 = Control (no fertilizer), T1 = RDF 100%, T2 = RDF 50%, T3 = *Azospirillum*, T4 = *Azotobacter*, T5 = Neem cake, T6 = Chicken manure, T7 = RDF 75% + *Azospirillum*, T8 = RDF 75% + *Azotobacter*, T9 = RDF 75% + neem cake, T10 = RDF 75% + chicken manure, T11 = RDF 50% + *Azospirillum*, T12 = RDF 50% + *Azotobacter* , T13 = RDF 50% + neem cake, T14 = RDF 50% + chicken manure, T15 = *Azospirillum* + *Azotobacter*, T16 = *Azospirillum* + neem cake, T17 = *Azospirillum* + chicken manure, T18 = *Azotobacter* + neem cake, T19 = *Azotobacter* + chicken manure, T20 = Neem cake + chicken manure

(17.35%) in treatment T15 (*Azospirillum* + *Azotobacter*) while lowest value was noted in treatment T5 (−19.19%) (Neem cake). In this study, dry weight of knob was negatively affected as compared to control plant (Fig. 5).

3.5 Fresh and dry weight of leaves

Different treatment of organic and inorganic fertilizer increased leaf fresh and dry weight. The maximum fresh weight of leaves (63.14%) was recorded in treatment T10 (75% RDF + chicken manure), while minimum fresh weight of leaves (0.005% g) was found in treatment T2 as compared to control plant (Fig. 4). Total dry biomass of leaf significantly increased in all treatment as compared to control plants (Fig. 5). Dry matter of leaves was maximum observed in treatment T7 (45.92%) and minimum (0.0011%) dry weight of leaves was observed in treatment T2.

3.6 Plant biomass

Application of fertilizer enhanced the total biomass of plant and maximum increment was found in treatment T14 (68.88%) and minimum in treatment T2 (0.005%) as compared to control plant (data not shown). The trends of total biomass increments in treatment was noted that in chronological order i.e. T14 (68.88%) >T8 (67.02%) > T7 (61.10%) >T10 (60.66%) >T9 (60.51%) >T5 (59.43%)> T6 (59.43%) > T18 (57.66%) > T3 (56.82%) >T19 (56.55%) >T13 (56.37%) > T11 (55.89%) > T4 (54.90%) > T12 (53.60%) > T16 (51.64%) > T20 (49.13%) >T1 (48.91%)> T15 (42.61%) >T17 (20.09%).

3.7 Yield

The maximum yield per plot was recorded in treatment T7 (61.83%) and minimum in T2 (0.005%) as compared to control. While, the treatment T8 (69.67%), T14 (57.62%), T10 (58.67%), T18 (58.33%) and T9 (56.89%) was also higher value (Fig. 6). The study also found out that maximum yield per hectare was noted in treatment T7 and minimum in treatment T2. Variation of total yield was finding out in descending order i.e. T7 (61.83%) >T8 (69.67%) > T10 (58.67%) >T18 (58.33%) >T9 (56.89%) >T14 (57.62%)> T6 (55.75%) > T3 (55.35%) > T11 (54.95%) >T19 (54.54%) >T13 (50.49%) > T4 (50.49%) > T20 (48.97%) > T12 (46.80%) > T16 (40.47%) > T5 (35.89%) >T17 (31.70%) > T1 (28.57%) > T15 (18.03%).

3.8 TSS and Vitamin C

The total soluble solid is the important quality traits in knol-khol, which is influences by the inorganic manures and organic manure that is directly involve in the total soluble solid enhancement. The maximum total soluble solid was recorded in treatment T9 (29.98%) which was found to be significantly superior over other treatments but statistically at par with T4 and T8 treatment (Fig. 7). Whereas the minimum total soluble solid was found in treatment T0. The maximum vitamin-C content was recorded in treatment T15 (23.44%) which was found significantly superior over other treatments but statistically at par with T5, T8 and T13 treatment, whereas the minimum vitamin-C content was found in treatment T0.

3.9 Principle component analysis (PCA)

Comparative effectiveness of different fertilizers was analyzed by principle component analysis (PCA). In this study bi-plot PC1 variants (41.11%) and PC2 (15.31%). Application of different organic and inorganic fertilizer increased growth and yield of knol-khol plant. Treatment T7, T8, T10 and T9 shows strong relation as compared to control plant (Fig. 8).

4 Discussion

Fertilizers including organic and bio-fertilizers are essential for nutrient supply to plant and enhancement of growth and productivity of crop plant. In this study, define that comparative effectiveness of different organic and inorganic fertilizer and its combination on growth morphology of knol-khol plant.

4.1 Plant growth

Higher increment of plant height was noted in treatment applied 75% RDF + *Azospirillum* (T7) than other treatment whereas the minimum plant height was found in treatment T0. This may be due to solubilization effect of plant nutrients by *Azospirillum* as evidenced by the increase in uptake of N, P and K (Kumar et al., 2012) and also due to its favourable effect on several physical properties of the soil. A study reported by Chaudhary and Singh (2018) organic matrix base slow release bio-fertilizer increased growth and productivity of wheat cultivar and enhanced the mobilization of nutrient from root to shoot of plant.

The maximum plant height was found in T8 (75% RDF + *Azotobacter*) at harvest (40.45 cm) stage, whereas the minimum plant height in T0 (Control) (25.56 cm) at same age. This may be due to solubilization effect of plant nutrients by *Azotobacter* as evidenced by the increase in uptake of different inorganic nutrients and minerals and also due to its favourable effect on several physical properties of the soil (Kumar et al., 2012; Wang et al., 2013; Singh et al., 2019).

Leaf number of the plant was also increased due to the application of organic manure and bio-fertilizers. The maximum increments of leaf number was noted

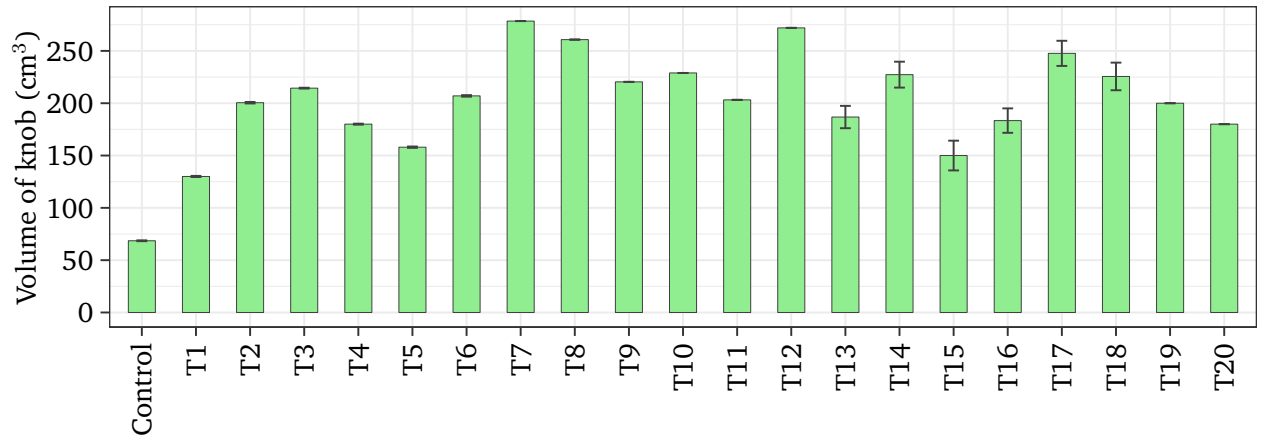

Figure 3. Effect of fertilizer management on knob size of knol-khol (*Brassica oleracea* var. gongylodes). T0 = Control (no fertilizer), T1 = RDF 100%, T2 = RDF 50%, T3 = *Azospirillum*, T4 = *Azotobacter*, T5 = Neem cake, T6 = Chicken manure, T7 = RDF 75% + *Azospirillum*, T8 = RDF 75% + *Azotobacter*, T9 = RDF 75% + neem cake, T10 = RDF 75% + chicken manure, T11 = RDF 50% + *Azospirillum*, T12 = RDF 50% + *Azotobacter* , T13 = RDF 50% + neem cake, T14 = RDF 50% + chicken manure, T15 = *Azospirillum* + *Azotobacter*, T16 = *Azospirillum* + neem cake, T17 = *Azospirillum* + chicken manure, T18 = *Azotobacter* + neem cake, T19 = *Azotobacter* + chicken manure, T20 = Neem cake + chicken manure

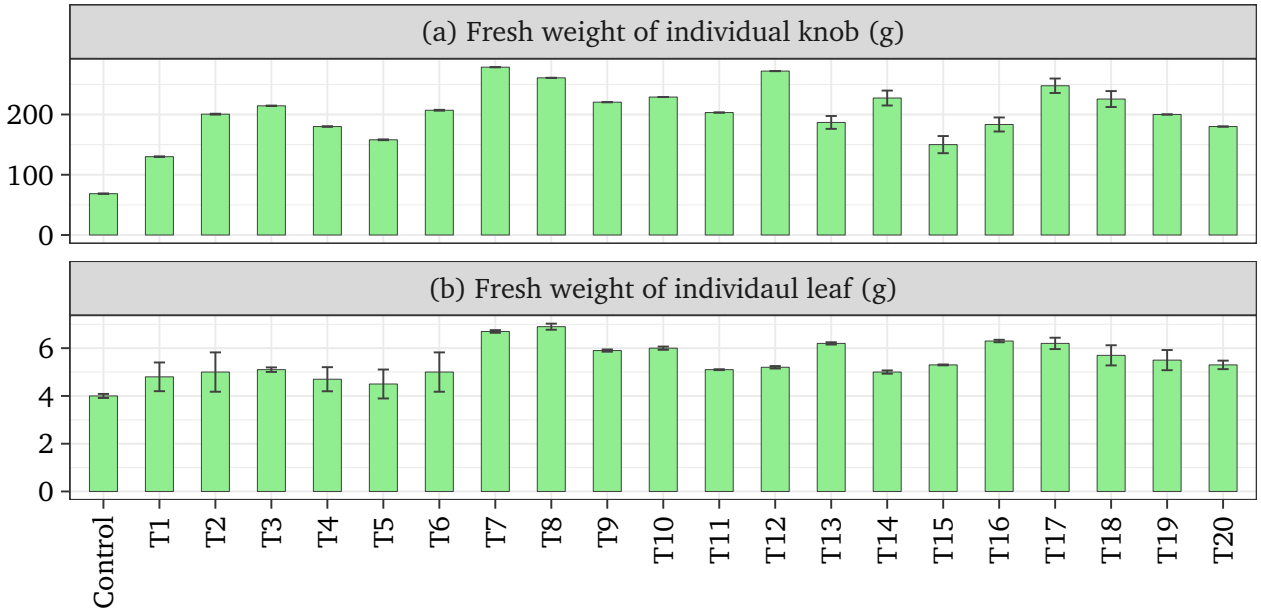

Figure 4. Effect of fertilizer management on fresh weight of (a) individual knob, and (b) individual leaf of knol-khol (*Brassica oleracea* var. gongylodes). T0 = Control (no fertilizer), T1 = RDF 100%, T2 = RDF 50%, T3 = *Azospirillum*, T4 = *Azotobacter*, T5 = Neem cake, T6 = Chicken manure, T7 = RDF 75% + *Azospirillum*, T8 = RDF 75% + *Azotobacter*, T9 = RDF 75% + neem cake, T10 = RDF 75% + chicken manure, T11 = RDF 50% + *Azospirillum*, T12 = RDF 50% + *Azotobacter* , T13 = RDF 50% + neem cake, T14 = RDF 50% + chicken manure, T15 = *Azospirillum* + *Azotobacter*, T16 = *Azospirillum* + neem cake, T17 = *Azospirillum* + chicken manure, T18 = *Azotobacter* + neem cake, T19 = *Azotobacter* + chicken manure, T20 = Neem cake + chicken manure

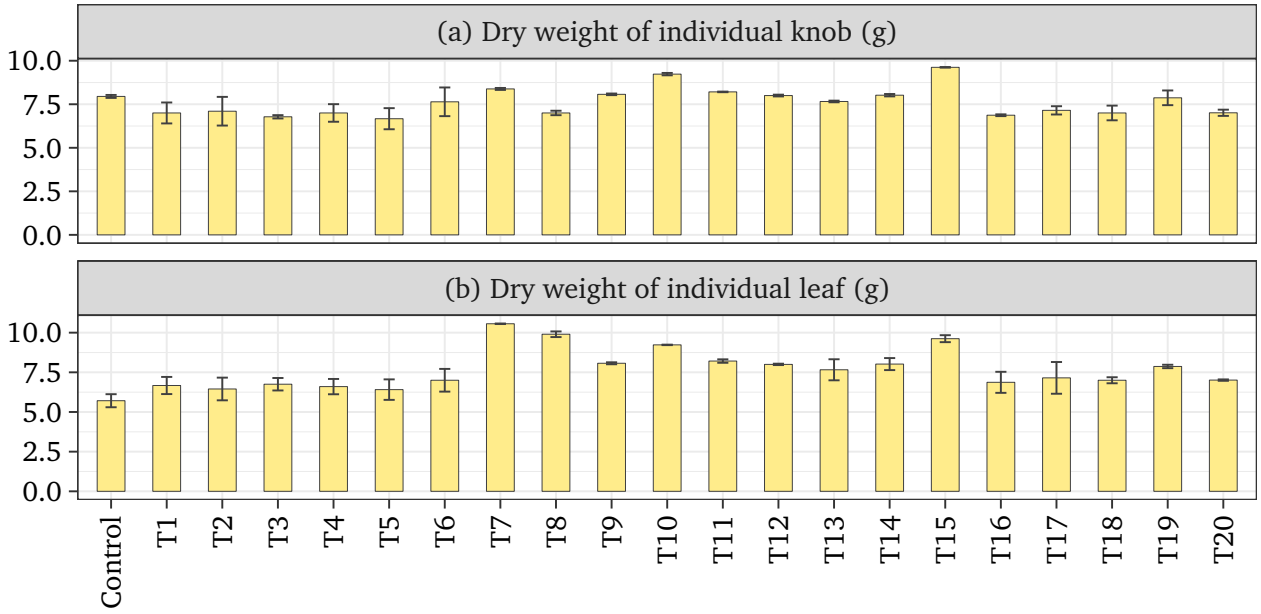

Figure 5. Effect of fertilizer management on dry weight of (a) individual knob, and (b) individual leaf of knol-khol (*Brassica oleracea* var. gongylodes). T0 = Control (no fertilizer), T1 = RDF 100%, T2 = RDF 50%, T3 = *Azospirillum*, T4 = *Azotobacter*, T5 = Neem cake, T6 = Chicken manure, T7 = RDF 75% + *Azospirillum*, T8 = RDF 75% + *Azotobacter*, T9 = RDF 75% + neem cake, T10 = RDF 75% + chicken manure, T11 = RDF 50% + *Azospirillum*, T12 = RDF 50% + *Azotobacter* , T13 = RDF 50% + neem cake, T14 = RDF 50% + chicken manure, T15 = *Azospirillum* + *Azotobacter*, T16 = *Azospirillum* + neem cake, T17 = *Azospirillum* + chicken manure, T18 = *Azotobacter* + neem cake, T19 = *Azotobacter* + chicken manure, T20 = Neem cake + chicken manure

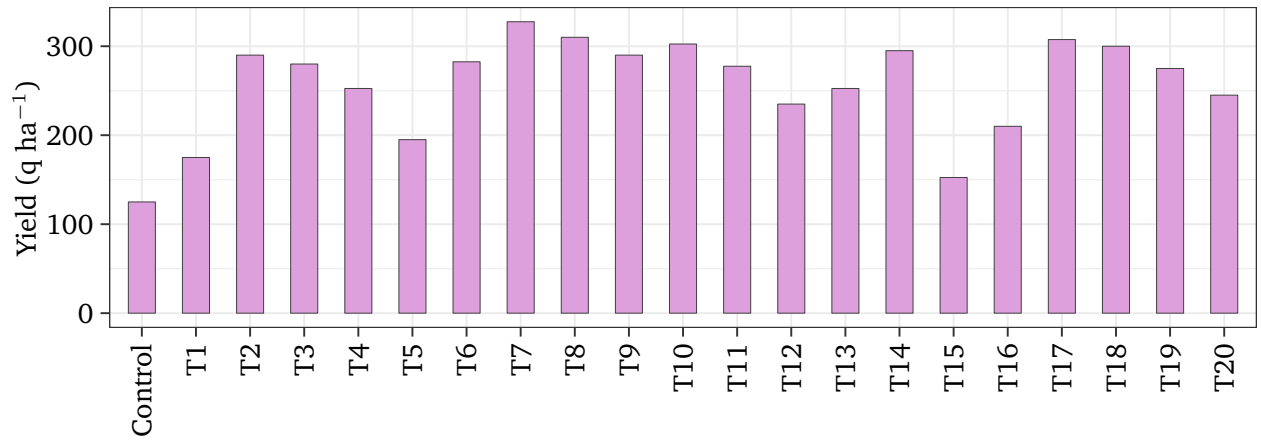

Figure 6. Effect of fertilizer management on knob yield of knol-khol (*Brassica oleracea* var. gongylodes). T0 = Control (no fertilizer), T1 = RDF 100%, T2 = RDF 50%, T3 = *Azospirillum*, T4 = *Azotobacter*, T5 = Neem cake, T6 = Chicken manure, T7 = RDF 75% + *Azospirillum*, T8 = RDF 75% + *Azotobacter*, T9 = RDF 75% + neem cake, T10 = RDF 75% + chicken manure, T11 = RDF 50% + *Azospirillum*, T12 = RDF 50% + *Azotobacter* , T13 = RDF 50% + neem cake, T14 = RDF 50% + chicken manure, T15 = *Azospirillum* + *Azotobacter*, T16 = *Azospirillum* + neem cake, T17 = *Azospirillum* + chicken manure, T18 = *Azotobacter* + neem cake, T19 = *Azotobacter* + chicken manure, T20 = Neem cake + chicken manure

in treatment T4 (*Azotobacter*) at 30 DAT, which was found to be significantly superior over the other treatments. While treatment T0 (control) shows the minimum number of leaves at 30 DAT. The increase in growth parameters could be because of certain growth-promoting substances secreted by the bio-fertilizers inoculants, which in turn might have led to good root development, better water absorption, and high uptake of nutrients from the soil body, which ultimately enhance number of leaves per plant (Chaterjee et al., 2005; Kumar et al., 2012). The maximum number of leaves at harvesting time recorded in T11 (50% RDF + *Azospirillum*), which was found to be significantly superior over other treatments.

4.2 Yield characteristics

The early knob initiation is a key factor for early yield of knol-khol. The initiation of knob is a varietal trait and also influences by the fertilizers. The high availability of plant nutrient in soil, leads quick conversion of vegetative to reproductive phase. The combined application of organic and inorganic fertilizers responses to improving results on knol-khol plant. The minimum days taken to knob initiation was recorded in treatment T7 (75% RDF + *Azospirillum*), which was found to be significantly lower over other treatments, whereas the maximum days taken to knob initiation was noticed in treatment T0. Bhusan et al. (2010) and Divya (2010) also reported that the similar study on knol-khol plant. The days to first knob harvest depended on the early knob initiation in knol-khol, because both the process is irreversible effects on each other maturity. Hence, the combination of NPK with bio-fertilizers responds well for early knob initiation to early maturity of crop. The minimum days taken to first knob harvest was recorded in treatment T7 (75% RDF + *Azospirillum*), which was found to be significantly lower over other treatments. In this contest bio-fertilizer improve the developmental stage of crop (Bhusan et al., 2010; Divya, 2010). The long harvesting duration, shows the long days availability of crop. The maximum days taken to final knob harvesting was recorded treatment T17 (*Azospirillum* + chicken manure), which was found to be significantly lower over other treatments but statistically at par with T8 treatment. The maximum days taken to final knob harvesting was noticed in treatment T6 (chicken manure).

The volume of knob is directly correlated with the knob size and weight. The combine application of organic fertilizers increases the volume of knob in knol-khol. The maximum volume of knob was recorded in treatment T7 (75% RDF + *Azospirillum*), while minimum in treatment T0 (control). The use of inorganic fertilizers with combination of bio-fertilizer increases the growth of plant, leaves, root proliferation and also the availability of nutrients for plants, which ultimately increase the knob size (Bhusan et al., 2010; Divya, 2010; Kumar et al., 2012). The diameter of knob was also increased due to combined application of organic manure and fertilizers. Maximum increments was found in treatment T8 (75% RDF + *Azotobacter*) and minimum in treatment T0 (control). The knob diameter of knol-khol is increases with the increases the photosynthetic activity and higher nutrients uptake, that results the increasing the knob diameter (Bhusan et al., 2010; Divya, 2010).

The length of knob was significantly influenced by the application of different organic and inorganic fertilizer. The maximum length of knob (6.65 cm) was recorded in treatment T7 (75% RDF + *Azospirillum*), which was found to be significantly superior over other treatments but statistically at par with T8 treatment. The minimum volume of knob (3.80 cm) was found in treatment T0. The length of knob increasing with the increasing the availability of essential nutrients in plant, increase good root proliferation, increase the number of leaves, increase photosynthesis and enhanced food accumulation, which ultimately enhance the knob diameter of knol-khol (Bhusan et al., 2010; Divya, 2010).

The maximum average weight of the knob (265.58 g) was recorded in treatment T7 (75% RDF + *Azospirillum*), which was found to be significantly superior over other treatments but statistically at par with T8 treatment. While, the minimum average weight of the knob (60.80 g) was found in treatment T0. The weight of knob is directly correlated with the total yield of crop. The weight of knob is increasing with the increasing the availability of nutrients, high uptake of nutrients, high photosynthetic rate and increase the nitrogen fixation ability which enhance the knob yield. Similar findings have been reported by Bhusan et al. (2010) and Divya (2010) in knol-khol.

The maximum fresh weight of leaves (380.78 g) was recorded in treatment T10 (75% RDF + chicken manure), which was found to be significantly superior over other treatments but statistically at par with T8 treatment. The minimum fresh weight of leaves (140.32 g) was found in treatment T0. The weight of fresh leaves increases due to enhancement of various nutrients in soil, which increases the photosynthetic activity in plant, that enhance the food accumulation in plant body. Similar findings have been reported by Bhusan et al. (2010) and Divya (2010) in knol-khol.

The highest average weight (646.46 g) of whole plant was recorded in treatment T14 (50% RDF + chicken manure), which was found to be significantly superior over other treatments but statistically at par with T8 treatment. On the other hand, the lowest (201.12 g) average weight of whole plant was found in treatment T0 (control). The combined effect of chemical fertilizers and chicken manures improves the soil condition, soil bulk density, aeration and enhance the availability of micro and micro nutrients

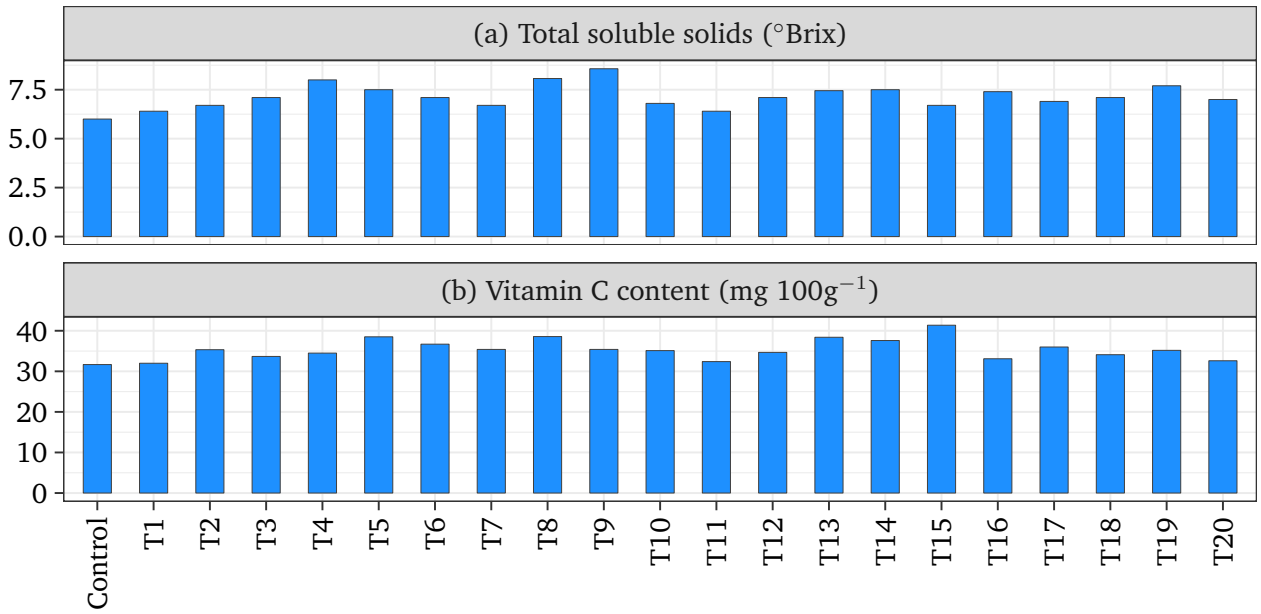

Figure 7. Effect of fertilizer management on dry weight of (a) individual knob, and (b) individual leaf of knol-khol (*Brassica oleracea* var. gongylodes). T0 = Control (no fertilizer), T1 = RDF 100%, T2 = RDF 50%, T3 = *Azospirillum*, T4 = *Azotobacter*, T5 = Neem cake, T6 = Chicken manure, T7 = RDF 75% + *Azospirillum*, T8 = RDF 75% + *Azotobacter*, T9 = RDF 75% + neem cake, T10 = RDF 75% + chicken manure, T11 = RDF 50% + *Azospirillum*, T12 = RDF 50% + *Azotobacter* , T13 = RDF 50% + neem cake, T14 = RDF 50% + chicken manure, T15 = *Azospirillum* + *Azotobacter*, T16 = *Azospirillum* + neem cake, T17 = *Azospirillum* + chicken manure, T18 = *Azotobacter* + neem cake, T19 = *Azotobacter* + chicken manure, T20 = Neem cake + chicken manure

and photosynthetic activity in plant which ultimately increases the total plant weight (Bhusan et al., 2010; Divya, 2010; Wang et al., 2013; Chaudhary and Singh, 2018).

The highest dry weight of leaves (10.56 g) was recorded in treatment T7 (75% RDF + *Azospirillum*), which was found to be significantly superior over other treatments but statistically at par with T8 treatment. The lowest (5.71 g) dry weight of leaves was observed in treatment T0. The combination of inorganic and biofertilizers directly involved to increase the growth and development of plant. The combination directly enhances the root growth, increases the uptake of nutrients and water from the soil, increase the leaf number and size, which directly involve for food accumulation in plant body (Bhusan et al., 2010; Divya, 2010; Singh et al., 2019).

The dry weight in knobs directly related to high dry matter content present in the knobs, which is directly or indirectly related to good nourishment of plant. The bio-fertilizers is a good sources of different nutrients because, it increased nitrogen fixing ability, microbial activity and total yield per plant. The maximum dry weight of knobs was recorded in treatment T15(*Azospirillum* + *Azotobacter*) which was found to be significantly superior over other treatments but statistically at par with T11 treatment. The minimum dry weight of knobs was recorded in the treatment T5 (neem cake). Application of organic manure and bio-fertilizers increased the weight of different part of plant (Bhusan et al., 2010; Divya, 2010; Singh et al., 2019).

The highest yield per plot was recorded in treatment T7 (75% RDF + *Azospirillum*), which was found to be significantly superior over other treatments but statistically at par with T8 treatment (data no shown). However, yield per plot was reduced in treatment T0 (control) as compared to other treatments. The increasing in yield is due to better root proliferation, good uptake of nutrients and water from the soil, high photosynthetic activity due to high leaf number that enhanced high food accumulation per plant. Similar findings have been reported by (Bhusan et al., 2010; Divya, 2010; Singh et al., 2019). The highest yield ha^{-1} was also recorded in treatment T7 (75% RDF + *Azospirillum*), which was found to be significantly superior over other treatments but statistically at par with T8 treatment. The simulative effect of *Azotobacter* might be attributed to its efficiency in supplying the growing plants with biologically fixed nitrogen, dissolved immobilized phosphorus and produced phytohormones, further these could stimulate nutrients absorption, as well as photosynthesis process which subsequently increased plant growth and yield (Bhu-

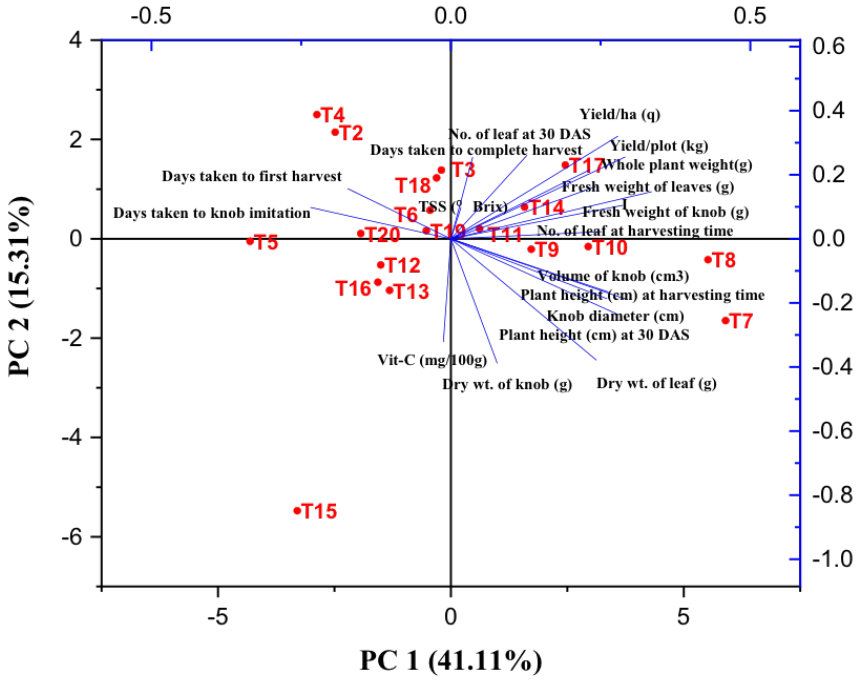

Figure 8. Correlation bi-plots of different treatments responses analyses by principle component (PCA). Symbol represents the standardized scores on PC1 (x-axis) and PC2 (y-axis) for the treatment variation applied on knol-khol (Brassica oleracea var. gongylodes) vegetable. Vector coordinates represent the correlations between standardized variables and principle components (PCs).

san et al., 2010; Divya, 2010; Chaudhary and Singh, 2018; Singh et al., 2019)).

4.3 Quality characteristics

The total soluble solid is the important quality traits in knol-khol, which is influences by the inorganic and organic manure that is directly involve in the total soluble solid improvement. The highest total soluble solid was recorded in treatment T9 (75% RDF + neem cake), which was found to be significantly superior over other treatments but statistically at par with T4 and T8 treatment. Whereas the minimum total soluble solid was found in treatment T0. The total soluble solid content was increased with the increase in the nutrient level in the treatments along with organic nutrient supplements (Divya, 2010). The increasing in nutrient level has been found to increase the TSS content in knol-khol. Same result was also reported by Divya (2010), Chaurasia et al. (2008) and Ghuge et al. (2007) on knol-khol plant. The maximum vitamin-C content was recorded in treatment T15 (*Azospirilium* + *Azotobacter*), which was found to be significantly superior over other treatments but statistically at par with T5, T8 and T13 treatment, whereas the minimum vitamin-C content was found in treatment T0. Similar findings were also reported by Ghuge et al. (2007), Chaurasia et al. (2008) and Divya (2010) in knol-khol. The increase in vitamin-C could be due to increased efficiency of microbial inoculants to fix atmospheric nitrogen and secrete growth promoting substances which might have accelerated the physiological processes like, synthesis of carbohydrates (Kamili et al.; Chaterjee et al., 2005).

5 Conclusions

Fertilizers are an important factor for plant growth and productivity. Bio fertilizers including organic manure are environmental friendly fertilizers and give better nutrient supply to plant and increase agriculture production and improve soil health. The study showed that the combination of organic fertilizers and manures give a better result of yield and quality parameters of knol-khol (*Brassica oleracea* var. gongylodes). Whereas all applied fertilizers increased growth and yield of plant but treatment T7 (75% RDF + *Azospirillum*) showed higher increment of yield (61.83% over control). Therefore, organic manures and bio-fertilizer are recommended to the farmer for better crops production and soil health. Other side treatments T7 (75% RDF + *Azospirillum*) should be used to enhance the production of knol-khol under the Garhwal region.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

Ashley MK, Grant M, Grabov A. 2005. Plant responses to potassium deficiencies: a role for potassium transport proteins. Journal of Experimental Botany 57:425–436. doi: 10.1093/jxb/erj034.

Bhusan A, Sharma AK, Sharma JP. 2010. Integrated nutrient management in knolkhol under Jammu and Kashmir condition. Journal of Research SKUAST-J 9:240–243.

Chaterjee B, Ghanti P, Thapa U, Tripathy P. 2005. Effect of organic nutrition in sprouting broccoli (*Brassica oleracea* L. var. *italica* Plenck). Vegetable Science 33:51–54.

Chaudhary IJ, Singh RP. 2018. Applied with organic matrix based slow release bio fertilizers. International Journal of Current Microbiology and Applied Sciences 7:3221–3238.

Chauhan ES, Tiwari A, Singh A. 2016. Phytochemical screening of Knol-Khol (*Brassica caulorapa*) owder and juice – A comparative study. International Journal of Home Science 2:123–126.

Chaurasia SNS, Singh AK, Singh KP, Rai AK, Singh CPN, Rai M. 2008. Effect of integrated nutrient management on yield and quality of cauliflower (*Brassica oleracea* L. var. botrytis) variety Pusa Snow Ball-K-1. Vegetable Science 35:41–44.

Divya CV. 2010. Studies on organic production techniques in Knolkhol (*Brassica oleracea* var. gongylodes L.). MS Thesis, University of Agricultural Science, Dharwad, Karnataka, India.

Ghuge TD, Gore AK, Jadhav SB. 2007. Effect of organic and inorganic nutrient sources on growth, yield and quality of cabbage (*Brassica oleracea* var. capitata). Journal of Soils and Crops 17:89–92.

Kamili I, Zargar M, Chattoo M. ???? Effect of microbial inoculants, chemical nitrogen and their combination on brinjal (*Solanum melongena* L.). Vegetable Science .

Kumar M, Bauddh K, Sainger M, Sainger PA, Singh JS, Singh RP. 2012. Increase in growth, productivity and nutritional status of rice (*Oryza sativa* L. cv. Basmati) and enrichment in soil fertility applied with an organic matrix entrapped urea. Journal of Crop Science and Biotechnology 15:137–144. doi: 10.1007/s12892-012-0024-z.

Kumar P, Shaunak I, Thakur AK, Srivastava DK. 2017. Health promising medicinal molecules in vegetable crops. Journal of Genetics and Genomes 1:102.

Malhotra H, Vandana, Sharma S, Pandey R. 2018. Phosphorus Nutrition: Plant Growth in Response to Deficiency and Excess. In Plant Nutrients and Abiotic Stress Tolerance. Springer, Singapore. doi: 10.1007/978-981-10-9044-8_7.

Mishra P, DasS A, Mishra N. 2014. Effect of integrated nutrient management on yield, quality and economics of knolkhol (*Brassica oleracea* L. cv. gongylodes). The Asian Journal of Horticulture 9:382–385. doi: 10.15740/has/tajh/9.2/382-385.

Singh V, Shah KN, Chaudhary IJ, Rana DK. 2019. Impact assessment of different organic manures on growth, morphology and yield of onion (*Allium cepa* L.) cultivar. Asian Journal of Agricultural Research 13:20–27. doi: 10.3923/ajar.2019.20.27.

Wang M, Zheng Q, Shen Q, Guo S. 2013. The critical role of potassium in plant stress response. International Journal of Molecular Sciences 14:7370–7390. doi: 10.3390/ijms14047370.

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