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Effect of plant spacing and potassium level on growth and yield of cabbage genotype Atlas-70

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ABSTRACT

An experiment was conducted in Horticulture Farm of Sher-e-Bangla Agricultural University to find out the effect of plant spacing and potassium fertilizer on growth and yield of cabbage. The experiment comprised of two factors viz. factor A: three plant spacing; S_1: 60 cm × 30 cm, S_2: 60 cm × 40 cm and S_3: 60 cm × 60 cm and factor B: four levels of potassium fertilizer; K_0: 0 kg; K_1: 90 kg; K_2: 120 kg and K_3: 150 kg K_2O ha^{-1}, respectively. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Different treatments showed significant variations on growth, yield components and yield of cabbage. The tallest plant 37.7 cm, diameter of head 19.1 cm and fresh weight of head^{-1} 1.87 kg were found in 60 cm × 60 cm (S_3) spacing and lowest was observed in 60 cm × 30 cm (S_1) spacing. On the other hand, the tallest plant 39.5 cm, highest diameter of head 18.8 cm, fresh weight of head^{-1} 1.62 kg and lowest values were observed respectively when 150 and 0 (zero) kg potassium in ha^{-1} was applied. For combined effect the tallest plant 40.2 cm, diameter of head 21.0 cm, fresh weight of head^{-1} 2.21 kg were found in $S_3 \times K_3$ and the lowest was observed in $S_1 \times K_0$ treatment combination. The highest gross yield (81.9 t ha^{-1}), marketable yield (61.3 t ha^{-1}) and benefit cost ratio (1.98) was noted from $S_2 \times K_3$ and the lowest from $S_1 \times K_0$ combination. So, 60 cm × 40 cm spacing with 150 kg K_2O ha^{-1} was the best for growth and yield of cabbage.

Introduction

Now a day, the global issue is to increase the productivity of any crop to meet up the food demands of the increasing population of the world. So, to meet up the demand higher yield of any vegetable crops in ha^{-1} can be achieved through the using of balance rates of fertilizer, different planting geometry, new cultivars and giving the better attention in water and pest control management. Ullah et al. (2013) stated that yield contributing characteristics are highly influenced at elevated level of spacing and became less at depress spacing. Earlier several citations in the literature along with Shumaker (1969) revealed that in generally the elevated level of plant spacing increased the head weight and the per cent of marketable cabbage. Plant spacing associated with plant density determines the successful production of cabbage. Silva et al. (2011) found the minimum and maximum yield at 1.0 m × 0.50 m and 0.60 m × 0.30 m spacing respectively when 20,000 & 54,644 plant ha^{-1} were existed in the field. Generally, increasing plant density decreased plant growth parameters like plant fresh weight, weight of unwrapped leaves, plant stem dimension and dry matter content decreased with increasing the plant spacing (Haque et al. 2015). On the other hand, judicious application of nutrient in the field can play a vital role in producing significant yield of any vegetables crops. Khan et al. (2002) stated that vegetable crop cabbage produced the highest yield 70 t ha^{-1} consumes 370 Kg N, 85 Kg P_2O_5 and 480 Kg K_2O from soil which indicates potassium fertilizer required in a vital amount. Due to deficiency of potassium fertilizer can result in marginal necrosis and it excess causes the head to open. Further, Sultana et al. (2012) stated that physiological process of crop may be hampered due to deficiency of potassium fertilizer. Studies the effect of planting geometry and potassium fertilizer on leaf and stem vegetables such as cabbage, celery and lettuce which are important cash crop in many parts of Asia and worldwide are limited or not up to standard. For this reason this study was undertaken to determine the optimum requirements of spacing and potassium level for cabbage in field culture that will provide a future reference for a research on these crop.

Materials and methods

Experimental location and climatic condition

The experiment was conducted at Horticulture Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh located in 24.09°N latitude and 90.26°E longitude.The land was medium high with adequate irrigation facilities belonging to the AEZ-28 (Agro-ecological Zone-28) categorized as Modhupur tract as classified by UNDP and FAO (1988). The soil was having a texture of sandy loam with pH 5.6. Soil samples of 0-15 cm depth were taken prior to transplanting of seedling to analyze the physical and chemical properties of soil.

Cultivation procedure

Soil of the seedbed and main land was well ploughed and converted into loose friable and dried masses to obtain good tilth. The surface of the soil was made smooth and well leveled by removing the weed stubbles and dead root. Well decomposed farm yard manure @ 3 kg m^{-2} was added at the time seedbed preparation. No chemical fertilizer was applied for rising of seedlings. The basal doses of manure and fertilizers were applied at the final ploughing during final preparation of the land. Manure and fertilizers were applied according to fertilizer recommendation guide (BARC, 2005) that presented in below-Full dose of cowdung, TSP, Gypsum and Boron were applied during final land preparation. The total amount of Urea and muriate of potash were applied in two installments. The first half was 15 and second half at 35 days after transplanting and light irrigation was applied followed by fertilizer application. To initiate the experiment 3.2 m ×1.2 m sized seedbed was prepared on 06 October, 2007 for raising cabbage seedling. For transplanting of the raising seedling 3.2 m × 1.2 m sized plot was prepared. Healthy 30 days old seedlings were transplanted to the main field.

Planting material

As a planting material the F_1 hybrid seeds of cabbage advanced line “Atlas-70” was used which produced by Sakata seed corporation, Japan. Seeds were treated by Vitavax 200 WP @ 2.5 g kg^{-1} of seed to protect some seed borne diseases.

Experimental treatment

This field trial comprised of two factors where as a factor A: three spacing level (S): *viz.* S_1 = 60 cm × 30 cm, S_2 = 60 cm × 40 cm and S_3 = 60 cm × 60 cm and factor B: four levels of potassium fertilizer (K): *viz.* K_0 = Control, K_1 = 90 Kg K_2O ha^{-1}, K_2 = 120 kg K_2O ha^{-1} and K_3= 150 kg K_2O ha^{-1}.

Transplanting of seedling

Before transplanting, the root of the seedlings was dipped in solution of Bavistin (2 gm L^{-1} of water). The 30 days older seedling having 5-6 true leaves were transplanted according to the treatment spacing.

Crop harvesting and data collection

The head of cabbage was harvested during the period from 12 to 15 February 2008 when the plants formed compact heads. The harvesting of the crop was done plot wise after testing the compactness of the cabbage head by hand. During and after harvesting morphological, yield and yield contributing data were collected according to the treatment from randomly selected cabbage sample.

Economic analysis

The cost of production was analyzed in order to find out the most reliable economic treatment of spacing and potassium fertilizer. All input and overhead cost was considered during the computing the economic analysis. The benefit cost ratio (BCR) was calculated by the following formula

$$\text{Benefit cost ratio} = \frac{\text{Gross return (Tk. ha}-^1)}{\text{Cost of cultivation (Tk. ha}-^1)}$$

Experimental design and statistical analysis

Experiment was conducted in Randomized Complete Block Design (RCBD) with three replications to know the effect of different plant spacing and doses of potassium fertilizer for the maximum growth, yield and economic return of cabbage. The recorded data on different growth; yield and yield contributing parameters were statistically analyzed to obtain the level of significance using computer based software "MSTAT-C" developed by Russell (1986). Mean separation was done at 5% level of probability following Least Significant Difference test (LSD).

Results and discussion

Effect of spacing on morphological characters

Plant height significantly varied among the different spacing and increased with the increasing of spacing (Table 1). The widest spacing S_3 (60 cm × 60 cm) produced the significantly tallest plant 37.7 cm. On the other hand, the moderate spacing S_2 (60 cm × 40 cm) produced the moderate stature plant while the shortest one was found in the closest spacing S_1 (60 cm × 30 cm).

Significant variation was recorded on length of stem of cabbage under different spacing level during the study period (Table 1). Stem length showed an increasing pattern with the increasing of pant spacing. The longest and shortest stems were 6.55 and 5.73 cm at widest spacing S_3 (60 cm × 60 cm) and closest spacing S_1 (60 cm × 30 cm) respectively. The moderate spacing S_2 (60 cm × 40 cm) also produced statistically similar stature of stem to widest spacing S_3 (60 cm × 60 cm).

The number of leaves $plant^{-1}$ showed significant variation among the different spacing as well as planting geometry (Table 1). Under this study, the number of leaves $plant^{-1}$ increased with increasing of spacing which was supported by Ullah et al. (2013). The highest number of leaves $plant^{-1}$ (20.0) was found in widest spacing S_3 (60 cm × 60 cm) and the lowest number (15.0) was in the closest spacing S_1 (60 cm × 30 cm).

Effect of spacing on the yield contributing characters of cabbage

Statistically significant variation was recorded among different plant spacing’s in respect of spreading of cabbage (Table 1). The widest spacing escalates the increasing of area covered by the cabbage. Significantly, the cabbage extended over an area up to 73.4 cm when it was grown at the widest spacing S_3 (60 cm × 60 cm) while limit an area up to 51.2 cm under the closest spacing S_1 (60 cm × 30 cm).

Table 1. Effect of plant spacing on morphological and yield contributing characters of cabbage advanced line "Atlas-70" during *rabi* (winter) season

Plant spacing (S)	Plant height (cm)	Stem length (cm)	Number of leaves plant^{-1}	Spreading of plant (cm)	Diameter of head (cm)	Thickness of head (cm)
S_1	35.7 c	5.73 b	15.0 c	51.2 c	16.4	10.3 b
S_2	36.8 b	6.33 a	17.0 b	62.4 b	17.7	11.2 a
S_3	37.7 a	6.55 a	18.0 a	73.4 a	19.1	11.8 a
$LSD_{0.05}$	0.776	0.428	0.34	5.72	1.54	1.11
LS	**	**	**	**	**	**

S_1 = 60 cm × 30 cm; S_2 = 60 cm × 40 cm; S_3 = 60 cm × 60cm, **indicates 1% level of significant, LSindicates the level of significant

Table 2. Effect of spacing on yield contributing characters of cabbage advanced line "Atlas-70" during *rabi* (winter) season

Spacing level (S)	Number of loose leaf plant^{-1}	Weight of loose leaf (g plant^{-1})	Fresh weight of head (kg plant^{-1})	Above ground dry matter of head (g plant^{-1})
S_1	16.2 b	639.7 c	0.81c	5.77 c
S_2	18.1 a	779.2 b	1.52 b	9.88 b
S_3	18.1 a	868.3 a	1.87 a	11.7 a
$LSD_{0.05}$	0.75	71.8	0.12	0.51
LS	**	**	**	**

S_1 = 60 cm × 30 cm; S_2 = 60 cm × 40 cm; S_3 = 60 cm × 60cm, **indicates 1% level of significant; LSindicates level of significant

Statistically significant variation was recorded among different plant spacing's in respect of diameter of head (Table 1). The results revealed that the diameter of head increased with the increasing of spacing and vigorous head 19.1 cm sized was produced by advanced line Atlas-70 when transplanting was done at the widest spacing followed by 60 cm × 60 cm spacing (S_3) and the weary head 16.4 cm sized was produced from the closest spacing as per 60 cm × 30 cm (S_1). Head thickness of cabbage differed significantly due to different plant spacing's (Table 1). From this finding it was observed that the thickness of head increased with the increasing of spacing. The highest thickness of head 11.8 cm was produced from widest spacing as per 60 cm × 60 cm (S_3) and the lowest (10.3 cm) was produced from the closest spacing as per 60 cm × 30 cm (S_1).

Statistically insignificant variation was found in leaf length at 30 days after transplanting (DAT) but at 45 DAT and 60 DAT it varied significantly among different plant spacing's (Fig. 1). At 30 DAT, the highest leaf length (18.6 cm) was found in S_2 (60 cm × 40 cm) and the lowest 18.2 cm was found in S_3 (60 cm × 60 cm) spacing. The highest leaf length at 45 DAT (28.2 cm) and 60 DAT (32.9 cm) were reported from the closest (60 cm × 30 cm) S_1 spacing. Moreover, the lowest leaf length at 45 DAT (26.5 cm) and 60 DAT (30.6 cm) was observed from (60 cm × 60 cm) S_3 plant spacing. It was found that the leaf length increased with the decreasing of plant spacing.

Significant variation was found in leaf breadth at different days after transplanting (DAT) among different plant spacing (Fig. 2). The highest leaf breadth 10.0 cm, 17.6 cm and 23.4 cm were observed at regular day's intervals from widest spacing 60 cm × 60 cm which was indicted by S_3. The lowest leaf breadth at 10.6 cm, 16.0 cm and 21.0 cm were found in closest 60 cm × 30 cm spacing (S_1). The results noted that the leaf breadth at different DAT was increased with wider spacing.

The number and weight of loose leaves plant^{-1} at harvest showed significant variations among the different spacing level (Table 2). But, Manasa et al. (2017) revealed that, number of loose leaf of cabbage did not differ significantly with the respect of plant spacing. The highest number of loose leaf 18.0 was found from 60 cm × 40 cm spacing (S_2) and 60 cm × 60 cm spacing (S_3) and weight of loose leaves (868.3 g) plant^{-1} was recorded from 60 cm × 60 cm spacing (S_3) spacing but the lowest was in 60 cm × 30 cm (S_1) spacing. This highest weight of loose leaf produced the highest dry matter weight (g plant^{-1}).

Fresh and above ground dry matter weight (g) of head of cabbage showed statistically significant variation among the spacing (Table 2). The highest fresh weight of head (1.87 kg plant^{-1}) and above ground dry matter weight of head plant^{-1} 11.7 g was observed in 60 cm × 60 cm (S_3) spacing while the lowest fresh weight of head 0.81 kg plant^{-1} and above ground dry matter weight of head 5.77 g plant^{-1} was found in 60 cm × 30 cm (S_1) spacing. It was revealed that with the increasing of plant spacing fresh weight of plant showed increasing trend. In case of wider spacing plant receive enough light and nutrients which leads to attain highest fresh weight of plant.

Statistically significant variation was observed in case of gross and marketable yield (t ha^{-1}) of cabbage under different spacing level (Fig. 3). The results revealed that the gross and marketable yield was increased with the increasing of spacing up to a certain level then decreased. The highest gross and marketable yield 71.2 and 54.0 t ha^{-1} respectively was found in moderate spacing 60 cm × 40 cm and the lowest gross and marketable yield 56.4 and 42.8 t ha^{-1} was in closest spacing as per 60 cm × 30 cm.

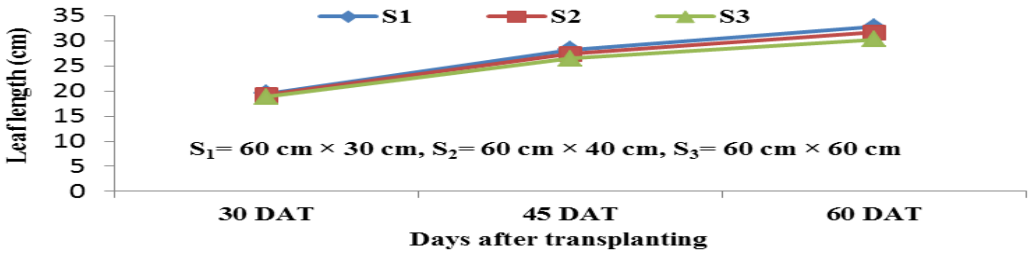

Figure 1: Effect of plant spacing on leaf length of Cabbage

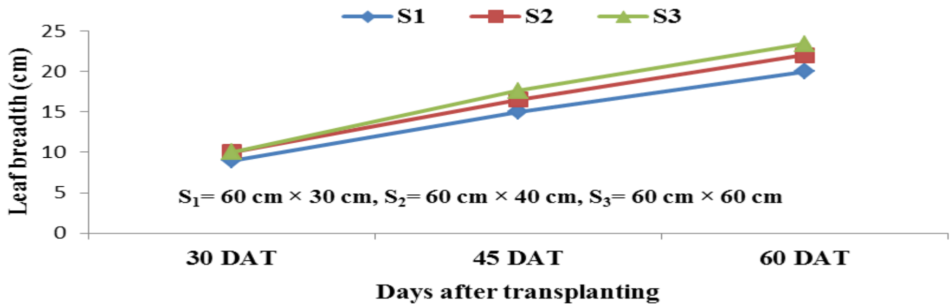

Figure 2: Effect of plant spacing on leaf breadth of Cabbage

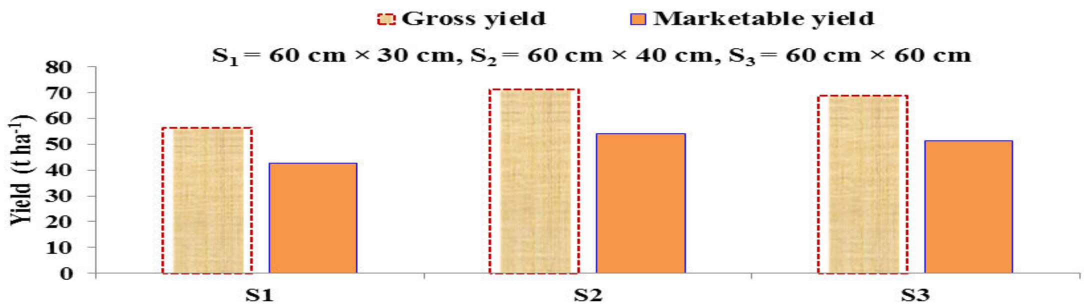

Figure 3. Effect of different spacing level on yield (t ha^{-1}) of Cabbage

Effect of potassium on morphological characters of cabbage

Plant height was significantly affected by the application of different doses potassium fertilizer and it increased in a linear fashion in response to potassium application (Table 3). Plant height increased to 39.5 cm that received 150 kg K_2O ha^{-1}. The shortest plant stature 32.5 cm was found when no potassium fertilizer was applied. Potassium played a role in cell division and this could be the reason for the linear increase in plant height was confirmed by Acquaah (2005). The stem length varied significantly due to the application of different levels of potassium fertilizer (Table 3). Stem length increased with the increasing of potassium level up to a certain level then decreased. The longest stem 6.54 cm was found when 120 kg ha^{-1} K_2O was applied while shortest was found in control treatment. Leaf number was affected significantly by application of potassium during the study (Table 3). Significantly, the highest number of leaves plant^{-1} 18.0 was recorded from 150 kg K_20 ha^{-1} treated plot (K_3) treatment whereas the lowest 14.0 number of leaves plant^{-1} was found from control (K_0) treatment.

Spreading of plant varied significantly due to the application of different levels of potassium (Table 3). It was stated that, spreading of plant increased with the higher levels of potassium. The application of highest 150 kg K_2O ha^{-1} in cabbage extended over an area up to 66.9 cm that was statistically similar with 90 kg and 120 kg K_20 ha^{-1}. Diameter of head varied significantly among the application of different levels of potassium (Table 3). The highest diameter of head 18.8 cm was found from 150 kg K_2O ha^{-1} (K_3) treatment and the lowest diameter of head 16.2 cm were observed from control (K_0) treatment. It was reported that the diameter of head increased with highest doses of potassium. Potassium fertilizer ensures maximum plant nutrients for proper growth and the results were the maximum diameter of head.

Head thickness of cabbage differed significantly among the application of different doses of potassium fertilizer (Table 3). From this finding it was observed that the thickness of head increased with the increasing potassium fertilizer. The highest thickness of head 12.0 cm was produced from application of the highest 150 kg ha^{-1} K_2O that was statistically similar with 90 and 120 kg ha^{-1} K_2O application. The lowest (10.3 cm) was produced from control treatment.

Leaf length of cabbage varied significantly due to the application of different levels of potassium at 30, 45 and 60 days after transplanting (DAT) (Fig. 4). The highest leaf length at 19.1 cm, 28.4 cm and 32.9 cm were found at 30, 45 and 60 days after transplanting respectively when the cabbage was treated by 120 kg ha^{-1} potassium fertilizer. In contrast, the lowest leaf length at 17.0 cm, 25.6 cm and 29.9 cm were noted at 30, 45 and 60 days after transplanting respectively when no potassium fertilizer was applied. It was reported that potassium helped vegetative growth that ensured maximum leaf length.

Leaf breadth differed significantly due to the application of different levels of potassium (Figure 5). The highest cabbage leaf breadth at 30 DAT (11.6 cm), 45 DAT (17.7 cm) and 60 DAT (23.22 cm) were found from (K_2) treatment when 120 kg K_2O ha^{-1} was applied. Again, the lowest leaf breadth at 30 DAT (10.5 cm), 45 DAT (16.0 cm) and 60 DAT (20.7 cm) were observed from (K_0) treatment when no potassium fertilizer was applied. It was reported that leaf breadth increased with the increasing of potassium level due to optimum cell elongation.

Table 3. Effect of different potassium level on morphological and yield contributing characters of cabbage advanced line "Atlas-70" during (*rabi*) winter season

Potassium level (K)	Plant height (cm)	Stem length (cm)	Number of leaves plant^{-1}	Spreading of plant (cm)	Diameter of head (cm)	Thickness of head (cm)
K_0	32.5 c	5.83 b	14.0 d	52.6 b	16.2 c	10.3 b
K_1	35.9 b	6.35 a	16.0 c	66.0 a	17.8 b	11.1 a
K_2	38.9 a	6.54 a	17.0 b	68.5 a	18.1 a	11.1 a
K_3	39.5 a	6.10 ab	18.0 a	66.9 a	18.8 a	12.0 a
$LSD_{0.05}$	0.89	0.49	0.39	0.89	1.50	1.11
LS	**	*	**	**	**	**

K_0= Control; K_1 = 90 kg K_20 ha^{-1}; K_2 = 120 kg K_20 ha^{-1}; K_3 = 150 kg K_20 ha^{-1}, **indicates 1% level of significant, *indicates 5% level of significant, LSindicates level of significant

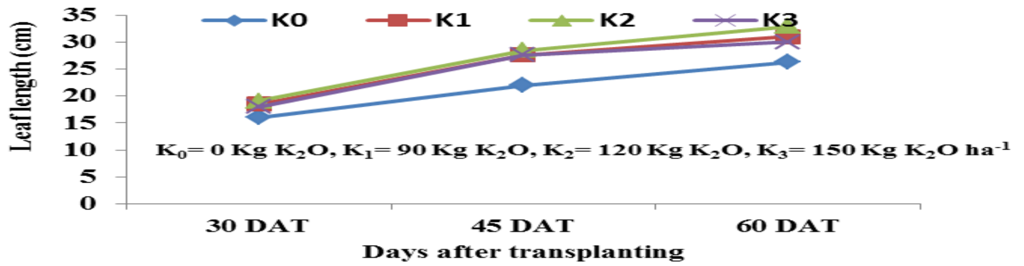

Figure 4. Effect of different potassium level on leaf length of Cabbage

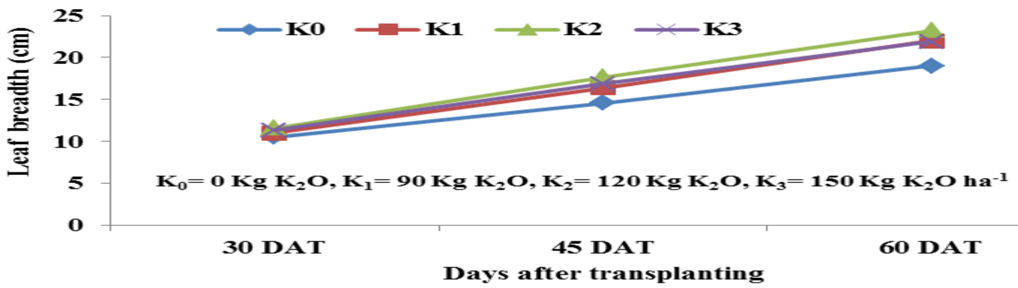

Figure 5: Effect of different potassium level on leaf breadth of Cabbage

Effect of potassium on yield contributing characters o cabbage

Potassium is an essential micronutrient which associated with the movement of water, nutrients and carbohydrates in plant tissue. It is also involved with enzyme activation within the plant which regulates the photosynthesis. Potassium also helps regulate the opening and closing of the stomata, which regulates the exchange of water vapor, oxygen and carbon dioxide. If potassium is deficient or not supplied in adequate amounts, it stunts plant growth and reduces yield. Potassium application @ 150 kg ha^{-1} accelerated the growth parameters *viz.* number of loose leaf and fresh weight of head during the harvesting stage. Potassium application K_3 (150 kg K_20 ha^{-1}) produced the highest number of loose leaf that was statistically at par with K_1 and K_2 treatment (Table 4).

Statistically significant variation was recorded for Fresh and above ground dry matter of head due to the application of different levels of potassium (Table 4). The highest Fresh and above ground dry matter of head 1.62 kg $plant^{-1}$ and 10.7 g $plant^{-1}$ was found from 150 kg K_20 ha^{-1} treated plot while lowest was found from control treatment.

Statistically significant variation was observed in case of gross and marketable yield (t ha^{-1}) of cabbage under different level of potassium fertilizer (Fig. 6). The results revealed that gross and marketable yield was increased with the increasing level of potassium fertilizer. The highest gross and marketable yield 73.9 and 55.5.0 t ha^{-1} respectively was found when crop was treated with highest 150 kg ha^{-1} K_2O and the lowest gross and marketable yield 51.2 and 3.6 t ha^{-1} was in control treatment.

Table 4. Effects of different potassium level on yield contributing characters of cabbage advanced line “Atlas-70" during (*rabi*) winter season

Potassium level (K)	Number of loose leaf $plant^{-1}$	Weight of loose leaf (g $plant^{-1}$)	Fresh weight of head (kg $plant^{-1}$)	Above ground dry matter of head (g $plant^{-1}$)
K_0	15.9 b	627.3 c	1.04 d	6.83 d
K_1	17.6 a	761.1 b	1.44 c	8.94 c
K_2	18.1 a	816.7 ab	1.53 b	10.00 b
K_3	18.3 a	844.4 a	1.62 a	10.70 a
$LSD_{0.05}$	0.87	82.9	0.14	0.59
LS	**	**	**	**

K_0 = Control; K_1 = 90 kg K_20 ha^{-1}; K_2 = 120 kg K_20 ha^{-1}; K_3 = 150 kg K_20 ha^{-1}, **indicates 1% level of significant; ^{LS}indicates level of significant

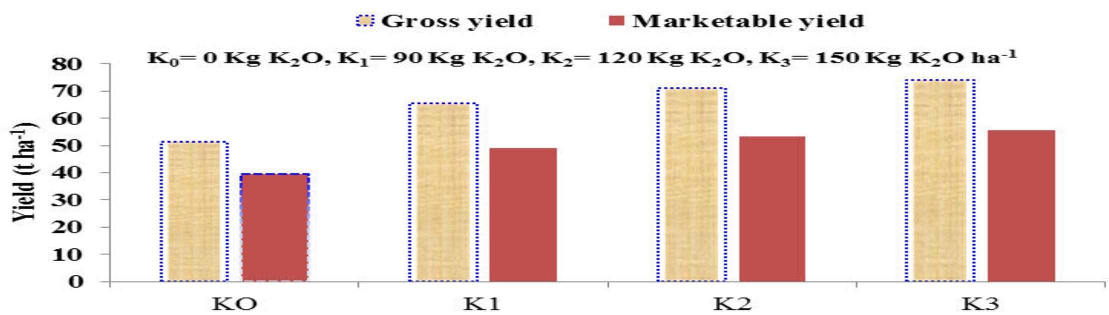

Figure 6. Effect of different potassium level of potassium fertilizer on yield of Cabbage

Interaction effects of spacing and potassium level on growth and yield of cabbage

Significant variation was found in plant height due to interaction effect of plant spacing and potassium level too (Table 5). The tallest plant 40.8 cm was recorded from $S_3 \times K_3$ treatment combination while the shortest plant 31.9 cm recorded from $S_1 \times K_0$ treatment combination. Combined effect of' plant spacing and levels of potassium in terms of stems length showed significant variation (Table 5). The longest stem 6.99 cm was found from combination of $S_2 \times K_2$ that was statistically similar with $S_2 \times K_1$ combination and the shortest stems 5.54 cm were found from $S_3 \times K_0$ treatment combination. Number of leaves $plant^{-1}$ did not differ significantly due to interaction effect of plant spacing and potassium fertilizer (Table 5). It ranged from 14.6 under combination of $S_1 \times K_0$ to 15.9 under combination of $S_3 \times K_2$.

The variation was observed due to the combined effect of plant spacing and levels of potassium in terms of spreading of plant were significant (Table 5). The highest spreading of plant 80.0 cm were noted from $S_3 \times K_3$ treatment combination. Nevertheless, the lowest spreading of plant 45.43 cm were recorded from $S_1 \times K_0$ treatment combination.

Combined effect of plant spacing and levels of potassium showed significant differences in respect of diameter of head (Table 5). The maximum diameter of head 21.0 was recorded from $S_3 \times K_3$

treatment and the minimum 14.6 cm was found from $S_1 \times K_0$ treatment combination. Significant variation was recorded due to the combined effect of plant spacing and levels of potassium in terms of thickness of head in cabbage (Table 5). The maximum thickness of head 13.1 cm was recorded from $S_3 \times K_3$ the minimum 9.60 cm was found from $S_1 \times K_0$ treatment combination. Leaf length differed significantly due to interaction effect different level of spacing and potassium fertilizer at 30, 45 and 60 days after transplanting (DAT) (Table 6). Leaf length among interaction effect increased greatly between 30 and 45 DAT sampling than increased slowly. The highest leaf length 33.8 cm was found at 60 DAT from the combination of $S_1 \times K_2$. Moreover, the lowest leaf length 16.5 cm at 30 DAT in $S_3 \times K_0$ combination.

The variation was recorded due to combined effect of plant spacing and levels of potassium in terms of leaf breadth at different DAT (Table 6). The highest leaf breadth at 30 DAT (11.9 cm), 45 DAT (18.0 cm) and 60 DAT (25.3 cm) were recorded from $S_3 \times K_2$ treatment combination the lowest leaf breadth at 30 DAT (10.2 cm), 45 DAT (15.3 cm) and 60 DAT (19.70 cm) were observed from $S_1 \times K_0$ treatment combination.

Number of loose leaf plant^{-1} showed significant variation between the interaction effect of spacing and potassium fertilizer (Table 7). The highest number of loose leaf (20.0) plant^{-1} was found from the interaction effect of $S_3 \times K_3$ that was statistically at par with $S_3 \times K_2$, $S_2 \times K_3$, $S_2 \times K_2$ and $S_2 \times K_1$. The lowest number of loose leaf (14.5) plant^{-1} was found from the interaction effect of $S_1 \times K_0$. Statistically significant variation was recorded due to the combined effect of plant spacing and levels of potassium in terms of number of compact leave per plant in cabbage (Table 7). The maximum number of compact leaves per plant (42.3) was recorded from $S_3 \times K_3$ treatment and the minimum (29.0) from $S_1 \times K_0$ treatment combination.

Table 5. Interaction effects of spacing and potassium level on morphological and yield contributing character of cabbage advanced line "Atlas-70" during (*rabi*) winter season

Interaction effect (S × K)	Plant height (cm)	Stem length (cm)	Number of leaves plant^{-1}	Spreading of plant (cm)	Diameter of head (cm)	Thickness of head (cm)
$S_1 \times K_0$	31.9 h	5.70 b	14.6	45.4 e	14.6 e	9.60 c
$S_1 \times K_1$	34.5 fg	5.83 b	14.7	51.7 d	16.8 d	10.7 b-e
$S_1 \times K_2$	37.6 de	5.80 b	15.3	53.4 d	16.9 d	10.0 de
$S_1 \times K_3$	38.7 b-d	5.80 b	14.8	54.4 d	17.2 cd	10.9 b-d
$S_2 \times K_0$	33.0 gh	6.30 ab	14.4	52.8 d	16.7 d	10.6 c-e
$S_2 \times K_1$	37.3 de	6.82 a	14.9	64.3 b	17.7 b-d	11.0 b-d
$S_2 \times K_2$	40.2 ab	6.99 a	15.3	66.1 b	18.2 b-d	11.7 bc
$S_2 \times K_3$	39.6 a-c	6.10 ab	14.6	66.4 b	18.2 b-d	11.3 bc
$S_3 \times K_0$	32.5 h	5.54 b	14.6	59.5 c	17.3 cd	10.7 b-e
$S_3 \times K_1$	36.0 ef	6.40 ab	15.4	76.5 a	18.8 bc	11.9 b
$S_3 \times K_2$	38.3 cd	6.84 a	15.9	77.5 a	19.1 b	11.7 bc
$S_3 \times K_3$	40.8 a	6.44 ab	15.4	80.0 a	21.0 a	13.1 a
$LSD_{0.05}$	1.55	0.86	--	3.73	1.55	1.12
LS	*	*	NS	**	**	**

S_1 = 60 cm × 30 cm; S_2 = 60 cm × 40 cm; S_3 = 60 cm × 60cm, K_0 = Control; K_1 = 90 kg K_2O ha^{-1}; K_2 =120 kg K_2o ha^{-1}; K_3 = 150 kg K_20 ha^{-1}, **indicates 1% level of significant, *indicates 5% level of significant, LSindicates level of significant, NSindicates non-significant.

Table 6. Interaction effects of spacing and potassium level on leaf length and breadth of cabbage advanced line "Atlas-70" at different days after planting (*rabi*) winter season

Interaction effect	Leaf length (cm)			Leaf breadth (cm)		
(S × K)	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
$S_1 \times K_0$	17.1 ab	26.5 bc	31.5 a-c	10.2 e	15.4 d	19.7 e
$S_1 \times K_1$	18.3 ab	28.3 ab	32.9 ab	10.6 c-e	15.9 b-d	21.5 cd
$S_1 \times K_2$	19.3 a	28.9 a	33.8 a	11.1 a-e	17.1 a-c	21.3 cd
$S_1 \times K_3$	18.7 ab	28.9 a	33.2 ab	10.4 de	15.6 cd	21.5 cd
$S_2 \times K_0$	17.5 ab	25.8 cd	29.9 bc	10.7 b-e	16.3 a-d	21.1 de
$S_2 \times K_1$	18.9 ab	27.9 ab	32.4 ab	10.8 a-e	16.6 a-d	21.8 cd
$S_2 \times K_2$	18.9 ab	27.8 a-c	32.4 ab	11.9 ab	17.9 a	22.9 bc
$S_2 \times K_3$	19.1 a	28.5 ab	32.8 ab	11.5 a-d	17.3 ab	22.9 bc
$S_3 \times K_0$	16.5 b	24.4 d	28.4 c	10.7 a-e	16.4 a-d	21.2 de
$S_3 \times K_1$	18.7 ab	26.6 bc	30.6 a-c	11.8 a-c	18.0 a	24.3 ab
$S_3 \times K_2$	19.1 a	27.6 a-c	32.5 ab	11.9 a	18.0 a	25.3 a
$S_3 \times K_3$	18.5 ab	27.6 a-c	30.9 a-c	11.7 a-d	17.9 a	22.6 cd
$LSD_{0.05}$	2.14	1.86	3.00	1.11	1.48	1.49
LS	*	*	*	**	**	*

S_1 = 60 cm × 30 cm; S_2 = 60 cm × 40 cm; S_3 = 60 cm × 60cm, K_0 = Control; K_1 = 90 kg K_20 ha^{-1}; K_2 = 120 kg K_20 ha^{-1}; K_3 = 150 kg K_20 ha^{-1}, **indicates 1% level of significant, *indicates 5% level of significant, LSindicates level of significant

Statistically significant variation was recorded for total dry matter of loose leaves due to the application of different levels spacing and potassium fertilizer (Table 7). The highest total dry matter of loose leaves (9.63 g) was observed from $S_3 \times K_3$ combination. In contrast, the lowest total dry matter of loose leaves (5.13 g) was observed from $S_1 \times K_0$ combination. It was noted that the dry matter of loose leaf increase with the increased in potassium.

Due to interaction effect of spacing and potassium fertilizer showed significant differences in respect of diameter, thickness and total dry matter of head plant^{-1} (Table 8). Significantly the maximum diameter of head 21.0 cm and thickness of head 13.1 cm was recorded from $S_3 \times K_3$ combination and the lowest diameter and thickness of head was found from the $S_1 \times K_0$ combination. The highest total dry matter of head per plant (13.98 g) was recorded from $S_3 \times K_3$ treatment combination and the lowest (4.51 g) was found from $S_1 \times K_0$ treatment combination.

The higher doses of potassium probably ensured vigorous growth of plant and consequently resulted in the highest diameter and thickness of heads. Due to interaction effect of different potassium level and spacing important parameter diameter of the stem differed significantly (Table 9). Diameter of stem was gradually increased with the increasing of potassium level along with all spacing level. Comparatively, the vigor size stem (3.95 cm and 3.94 cm) was produced by the experimented variety which was treated by 150 kg (K_3) and 120 $K_2$0 in ha^{-1} (K_2) along with 60 cm × 40 cm (S_2) and 60 cm × 60 cm spacing (S_3) respectively. The lowest size stem was produced from the closest spacing along with control level of potassium fertilizer (Table 9). Length of stem was gradually increased with the increasing of potassium level along with all spacing. The longest stem 9.56 cm was found when the variety was treated by 150 kg $K_2$0 ha^{-1} along with closes spacing S_1 (60 cm × 30 cm) (Table 9). The statistical analysis of data revealed that interaction of different potassium levels and spacing significantly influenced fresh weight of stem of cabbage. The mean Table shows that highest fresh weight of stem (52.3 g) was noted when lowest number of plant population in ha^{-1} was treated by the highest level of potassium. The lowest fresh weight of stem weight (35.3 g and 37.1 g) was found when highest number of plant population in ha^{-1} was treated without potassium (Table 9).

Table 7. Interaction effect of different spacing and potassium level on yield contributing characters of cabbage advanced line "Atlas-70" during (*rabi*) winter season

Interaction effect (S × K)	Number of loose leaf plant^{-1}	Number of compact leaf plant^{-1}	Total dry matter of loose leaf (g plant^{-1})
$S_1 \times K_0$	14.5 e	29.0 g	5.13 g
$S_1 \times K_1$	16.7 cd	32.3 f	6.56 ef
$S_1 \times K_2$	16.8 cd	33.8 ef	6.70 ef
$S_1 \times K_3$	16.9 b-d	33.5 ef	6.65 cf
$S_2 \times K_0$	16.9 b-d	37.5 cd	5.90 fg
$S_2 \times K_1$	18.3 a	39.9 a-c	7.20 de
$S_2 \times K_2$	18.6 ab	39.1 bc	8.83 ab
$S_2 \times K_3$	18.6 ab	40.4 a-c	7.81 cd
$S_3 \times K_0$	16.3 d	35.6 dc	6.45 ef
$S_3 \times K_1$	17.8 b-d	38.7 bc	8.61 bc
$S_3 \times K_2$	18.9 a	41.1 ab	9.13 ab
$S_3 \times K_3$	19.5 a	42.4 a	9.63 a
$LSD_{0.05}$	1.51	2.83	0.94
LS	**	**	*

S_1 = 60 cm × 30 cm; S_2 = 60 cm × 40 cm; S_3 = 60 cm × 60cm, K_0 = Control; K_1 = 90 kg $K_2$0 ha^{-1}; K_2 = 120 kg $K_2$0 ha^{-1}; K_3 = 150 kg $K_2$0 ha^{-1}, **indicates 1% level of significant, *indicates 5% level of significant, LSindicates level of significant.

Table 8. Interaction effect of different spacing and potassium level on yield contributing characters of cabbage advanced line "Atlas-70" during (*rabi*) winter season

Interaction effect (S × K)	Diameter of head (cm)	Thickness of head (cm)	Total dry matter of head (g plant^{-1})
$S_1 \times K_0$	14.6 e	9.56 e	4.51 f
$S_1 \times K_1$	16.8 d	10.7 b-e	5.95 e
$S_1 \times K_2$	16.9 d	10.0 de	6.00 e
$S_1 \times K_3$	17.2 cd	10.9 b-d	6.62 e
$S_2 \times K_0$	16.7 d	10.6 c-e	7.83 d
$S_2 \times K_1$	17.7 b-d	11.0 b-d	9.22 c
$S_2 \times K_2$	18.2 b-d	11.7 bc	10.9 b
$S_2 \times K_3$	18.2 b-d	11.3 bc	11.5 b
$S_3 \times K_0$	17.3 cd	10.7 b-e	8.14 d
$S_3 \times K_1$	18.8 bc	11.9 b	11.7 b
$S_3 \times K_2$	19.1b	11.7 bc	13.0 a
$S_3 \times K_3$	21.0 a	13.1 a	13.9 a
$LSD_{0.05}$	1.55	1.12	1.02
LS	**	**	**

S_1 = 60 cm × 30 cm; S_2 = 60 cm × 40 cm; S_3 = 60 cm × 60cm, K_0 = Control; K_1 = 90 kg $K_2$0 ha^{-1}; K_2 = 120 kg $K_2$0 ha^{-1}; K_3 = 150 kg $K_2$0 ha^{-1}, **indicates 1% level of significant, LSindicates level of significance.

Table 9. Interaction effect of different spacing and potassium level on yield contributing characters of cabbage advanced line "Atlas-70" during (*rabi*) winter season

Interaction effect (S × K)	Diameter of stem (cm)	Length of stem (cm)	Fresh weight of stem (g)
$S_1 \times K_0$	2.93 d	8.22 de	35.3 c
$S_1 \times K_1$	3.61 a-c	9.33 ab	46.4 b
$S_1 \times K_2$	3.72 a-c	9.22 a-c	46.1 b
$S_1 \times K_3$	3.33 cd	9.56 a	46.4 b
$S_2 \times K_0$	3.40 b-d	7.80 e	37.1 c
$S_2 \times K_1$	3.70 a-c	8.20 de	48.2 ab
$S_2 \times K_2$	3.94 a	8.33 c-e	50.1 ab
$S_2 \times K_3$	3.90 ab	8.80 a-d	50.2 ab
$S_3 \times K_0$	3.33 cd	8.01 de	38.6 c
$S_3 \times K_1$	3.83 a-c	8.50 b-e	50.6 ab
$S_3 \times K_2$	3.83 a-c	8.30 de	50.1 ab
$S_3 \times K_3$	3.95 a	8.44 b-e	52.3 a
$LSD_{0.05}$	0.46	0.82	5.05
LS	**	*	**

S_1 = 60 cm × 30 cm; S_2 = 60 cm × 40 cm; S_3 = 60 cm × 60cm, K_0 = Control; K_1 = 90 kg K_20 ha^{-1}; K_2 = 120 kg K_20 ha^{-1}; K_3 = 150 kg K_20 ha^{-1}, **indicates 1% level of significant, *indicates 5% level of significant, ^{LS}indicates level of significance

Table 10. Interaction effect of different spacing and potassium level on yield contributing characters and yield of cabbage advanced line "Atlas-70" during (*rabi*) winter season

Interaction effect (S × K)	Fresh weight of root (g)	Gross yield (t ha^{-1})	Marketable yield (t ha^{-1})
$S_1 \times K_0$	20.8 d	45.2 h	35.5 h
$S_1 \times K_1$	25.9 c	56.3 fg	42.4 fg
$S_1 \times K_2$	25.1 c	60.4 ef	45.5 ef
$S_1 \times K_3$	25.9 c	63.5 de	47.8 de
$S_2 \times K_0$	23.7 cd	55.4 fg	43.4 e-g
$S_2 \times K_1$	30.2 ab	67.3 cd	50.7 cd
$S_2 \times K_2$	32.4 a	80.2 a	60.4 a
$S_2 \times K_3$	33.3 a	81.9 a	61.3 a
$S_3 \times K_0$	26.3 bc	53.1 g	40.0 g
$S_3 \times K_1$	31.1 a	72.6 bc	53.7 bc
$S_3 \times K_2$	32.3 a	72.8 bc	53.9 bc
$S_3 \times K_3$	34.5 a	76.3 ab	57.5 ab
$LSD_{0.05}$	4.05	7.02	7.97
LS	**	*	**

S_1 = 60 cm × 30 cm; S_2 = 60 cm × 40 cm; S_3 = 60 cm × 60cm, K_0 = Control; K_1 = 90 kg K_20 ha^{-1}; K_2 =120 kg K_20 ha^{-1}; K_3 = 150 kg K_20 ha^{-1}, **indicates 1% level of significant, *indicates 5% level of significant, ^{LS}indicates level of significance.

Due to interaction effect of spacing and potassium level fresh weight of root showed significant differences. The S_3 (60 cm × 60 cm) spacing along with potassium level K_3 (150 kg K_20 ha^{-1}) produced highest fresh weight of root (34.5 g) that was statistically similar with $S_3 \times K_1$, $S_3 \times K_2$, $S_2 \times K_2$, $S_2 \times K_3$ and $S_2 \times K_1$ interaction. The lowest fresh weight of root 20.8 g was found from the $S_1 \times K_0$ interaction (Table 10). Interaction effect of different spacing and potassium level had significant effect on gross and marketable yield (t ha^{-1}). Different treatment combination showed different gross and marketable yield. The highest gross yield (81.9 t ha^{-1}) and marketable yield (61.3 t ha^{-1}) was observed with the treatment combination of $S_2 \times K_3$ which was statistically similar with $S_2 \times K_2$. The lowest gross yield (45.2 t ha^{-1}) and marketable yield (35.5 t ha^{-1}) was obtained with $S_1 \times K_0$ (Table 10).

Economic Analysis

Economic analysis was done with a view to observing the proportional cost and benefit under different spacing and potassium level combination for cabbage cultivation. Input and overhead costs were considered for all the operations from raising of seedling to harvesting of cabbage were recorded for $unit^{-1}$ plot and converted into cost ha^{-1}. The price of cabbage was obtained from personal communication with cabbage producers and retailers around the nearest market to the study area.

The cultivation cost was gradually increased with the increasing doses of potassium level.The total cost of cultivation ranged from Tk. 1, 44,568 ha^{-1} to Tk. 1, 54, 632 ha^{-1}. The highest cost of cultivation Tk. 1, 54,632 ha^{-1} was involved when 150 kg K_20 ha^{-1} was applied along with all spacing. The lowest cost of production Tk. 1, 44,568 $ha^{-1}$was found when any potassium fertilizer did not apply (Table 11). The combination of plant spacing and level of potassium showed different gross return under the trial. The highest gross return Tk. 3,06,500 ha^{-1}, gross margin (Tk. 1,51,868) and benefit cost ratio 1.98 was obtained from the combination of 150 kg K_20 ha^{-1} along with 60 cm × 40 cmspacing followed by 120 kg K_20 ha^{-1} along with 60 cm × 40 cmspacing (Table 11). The lowest gross return Tk. 1, 77,350, gross margin Tk. 32,782 ha^{-1} andbenefit cost ratio 1.23 was found in 0 kg K_20 ha^{-1} along with 60 cm × 30 cm spacing (Table 11). From economic point of view, it is apparent from the above results that the combination of 150 kg K_20 ha^{-1} along with 60 cm × 40 cm was more profitable than rest of the other.

Table 11. Economic study of cabbage production as influenced by the interaction effect of spacing and potassium level during (*rabi*) winter season

Treatment	Marketable yield (t ha^{-1})	Cost of cultivation (Tk. ha^{-1})	Gross return (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	Benefit cost ratio
$S_1 \times K_0$	35.5	1,44,568	1,77,350	32,782	1.23
$S_1 \times K_1$	42.4	1,50,607	2,12,200	61,593	1.41
$S_1 \times K_2$	45.5	1,52,620	2,27,600	74,980	1.49
$S_1 \times K_3$	47.8	1,54,632	2,39,200	84,568	1.55
$S_2 \times K_0$	43.4	1,44,568	2,17,100	72,532	1.50
$S_2 \times K_1$	50.7	1,50,607	2,53,700	1,03,093	1.70
$S_2 \times K_2$	60.4	1,52,620	3,02,150	1,49,530	1.97
$S_2 \times K_3$	61.3	1,54,632	3,06,500	1,51,868	1.98
$S_3 \times K_0$	40.0	1,44,568	2,00,000	55,432	1.38
$S_3 \times K_1$	53.7	1,50,607	2,68,550	1,17,943	1.78
$S_3 \times K_2$	53.9	1,52,620	2,69,950	1,17,330	1.77
$S_3 \times K_3$	57.5	1,54,632	2,87,400	1,32,768	1.86

Note: Price of cabbage Tk. 5000 tone^{-1}

Conclusion

It is concluded that application of potassium fertilizers had significant and positive effect on the growth and yield of cabbage. There were significant differences among the different morphological and yield contributing characters of cabbage advanced line "Atlas-70" during performing under field condition due to different level of potassium fertilizer and spacing. Interactions of potassium fertilizer and spacing were significant on production of cabbage. The highest gross and marketable yield of cabbage advanced line of "Atlas-70" was found when elevated level of potassium fertilizer and moderate spacing was applied. The cost benefit analysis indicated that, growers can get reasonable economic benefit by considering potassium application for cabbage production. It is, therefore, recommended that potassium fertilizers should be introduced and included in the fertilizer packages of the cabbage growers in the study area and other areas of the country with similar soil conditions.

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