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Response of Ajowan (*Trachyspermum ammi* L.) to different seed rates

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Abstract
In order to develop a better cultivation method for BARI Ajowan-1, it is very important to identify the seed rate first. Therefore, this experiment was conducted at Spices Research Sub-Centre, Faridpur during the rabi season in 2019-20 and 2020-21. Total of five seed rates (3.0, 3.5, 4.0, 4.5, and 5.0 kg/ha) were evaluated here with three replications, and a randomized complete block design was followed. From two years' results, the 2019-20 season showed better performances due to positive environmental conditions. Maximum traits, e.g. plant height, branch number, umbel number, yield, etc. showed significant responses by different seed rates. Among this seed rate, the seed yield obtained highest (987.48 kg/ha) at 4.5 kg/ha. Among all yield and yield contributing traits, branches per plant, 1000-seed weight, and umbel per plant were the important traits for variability creation and were mostly responsible for seed yield. From these findings, it is concluded that for better growth and yield 4.5 kg/ha seed rate is best for Ajowan cultivation.

Keywords: Seed rate, BARI Ajowan-1, seed yield, correlation coefficient and regression

Introduction
Ajowan is a spice that is commonly found in Bangladeshi households, but it is not widely used. It is a minor spice crop in Bangladesh and is grown in a relatively small area. Ajowan seeds come in a range of colors, from light olive green to brown. They are a unique spice that not only adds flavor but also has health benefits. Ajowan (*Trachyspermum ammi* L.) belongs to the Apiaceae family and is an industrial medicinal plant (Boskabady *et al*., 2014; Niazian *et al*., 2017) [7, 16-17]. Arid and semi-arid regions of Egypt, East of India, and northwest, central, and eastern parts of Iran are the main growing area of Ajowan. (Ashraf and Orooj 2006; Joshi 2000; Moosavi *et al*., 2015; Niazian *et al*., 2017; Noori *et al*., 2017) [1, 11, 14, 16-17,]. This plant is valuable for its active substances of seeds which are used for medicinal purposes (Dalkani *et al*., 2011) [9]. Essential oil with about 50% content of thymol along with γ-terpinene (3.83%) and cymene (3.37%), containing in ajowan seeds which has a potent germicide, anti-spasmodic and fungicidal effect (Bhatt *et al*., 2018) [8]. Ajowan seeds are commonly used as a natural solution for stomach discomfort caused by indigestion. Its seeds and oils are used mainly for its stimulant, antioxidants, preservatives, aromatic and carminative properties. Flavoring of foods is another significant use of ajowan seeds (Muvel *et al*., 2015) [15].

Farmers throughout Bangladesh grow ajowan for their own domestic use, but the amount produced is not enough to meet the commercial demand of the country. In fact, in 2021-22, only 9.80 metric tons of ajowan were produced from 27.35 acres of land, with an average yield of 885 kg/ha (BBS, 2023) [6]. It is crucial that we increase Ajowan production in Bangladesh. By doing so, we can benefit from this medicinal herb and incorporate it into traditional dishes for its positive effects on our digestive tract. Additionally, increasing Ajowan production can help alleviate pressure on other medicinal herbs. Moreover, exporting ajowan to other countries can be profitable for our country. However, there is a lack of information on cultivating Ajowan seeds in Bangladesh, which is leading to low production. Factors such as seed rate, sowing time, and fertilizer levels are important for profitable production, but inappropriate seed rates are particularly limiting. Research on this factor can surely enhance the profitable production of Ajowan.

The seed rate is a crucial factor in agriculture that affects crop establishment and stand density. Proper management of seed rate is essential for determining plant spacing, nutrient utilization, and resource allocation, which ultimately affects plant growth and yield (Kaur *et al*., 2019) [12]. The ideal seed rate plays a vital role in achieving maximum crop yield. A higher seed rate results in more plant population, leading to competition among plants for essential resources like water, nutrients, and sunlight. This competition can negatively impact the quality and yield of the crop. On the other hand, a lower seed rate leads to a lesser number of plants per unit area, resulting in reduced crop yield (Attarde and Khuspe, 1989) [4]. Rajput *et al.* (1989) [19] found that increasing the seed rate led to the highest grain yield, while a low seed rate resulted in the minimum grain yield. The optimum seed rate is responsible for maintaining an ideal plant density, allowing plants to utilize all the environmental factors like water, air, light, soil, etc. while minimizing intra-species and extra-species competition (Alizadeh & Koucheki, 1995) [2]. While there is extensive research on the impact of seed rate on various crops, there is limited information on its specific effect on Ajwan cultivation.

It is crucial to determine the appropriate seed rate for Ajowan production in Bangladesh. A trial was conducted to identify the optimal seed rate that positively impacts the growth, yield, and yield components of Ajowan.

Materials and Methods

The experiment has been conducted at Spices Research Sub-Centre, Faridpur, Bangladesh for two consecutive years 2019-20 and 2020-21 during the rabi season to find out the optimum seed rate of Ajowan to assure best cultivation practice. This experiment was designed with five different seed rates as 3.0,3.5,4.0,4.5 and 5.0 kg/ha. The experimental site is belonging to Agro-Ecological Zone (AEZ) no. 12 (Low Ganges River Floodplain). The geographic coordinates of the trial site are 23°11'N and 89°09'E. While its elevation is about 12 meters above sea level. The soil of the experimental field was clay loam in texture having 7.6-8.1 soil p^H. The experiment was laid out in a Randomized Complete Block Design with three replications. The unit plot size was 3m x 2.0m. BARI Ajowan-1 was used as a test crop. Seeds were sown in mid-November, maintaining 40 cm x 10 cm spacing. Before seed sowing, it was treated with Ridomil Gold MZ 68 WG (Mancozeb + Metalaxyl) for 5 minutes. In addition to 5 t/ha of cow dung, the crop was fertilized with $N_{80}P_{35}K_{68}S_{20}B_{1.5}$ kg/ha. The entire amount of cow dung, P, K, and S were applied during final land preparation. The N was applied with 3 equal splits at 20, 40, and 60 days after sowing. To control foot rot disease, the crop was sprayed with `Autostin' (Carbendazim) @ 2g/L of water at 30 and 40 DAS. All other recommended management practices were followed for each treatment. The crop was harvested from 15 to 25 March.

Data on the plant height (cm), number of branches per plant, number of umbels per plant, number of umbellets per umbel, number of seeds per umbel, 1000-seed weight (g), and seed yield (kg/ha) were recorded.

The analysis of variance for individual traits was carried out using R software version 4.3.1 (R,2017).

To observe associations among the studied traits, a correlation analysis was performed with R software (R,2017) using the 'metan' package (Olivoto, 2020) [18].

A multiple regression analysis was performed to determine the extent of the relationship between yield with the other studied traits. The analysis and visualization were performed using the 'ggplot2' (Wickham, 2009) [22] package in R software (R, 2017) [21].

Monthly average air temperature, average relative humidity, and total rainfall for the trial location during 2019-20 and 2020-21 were collected from the digital weather station which is established in SRSC, Faridpur. Weather data during the growing season are illustrated in Figure 1.

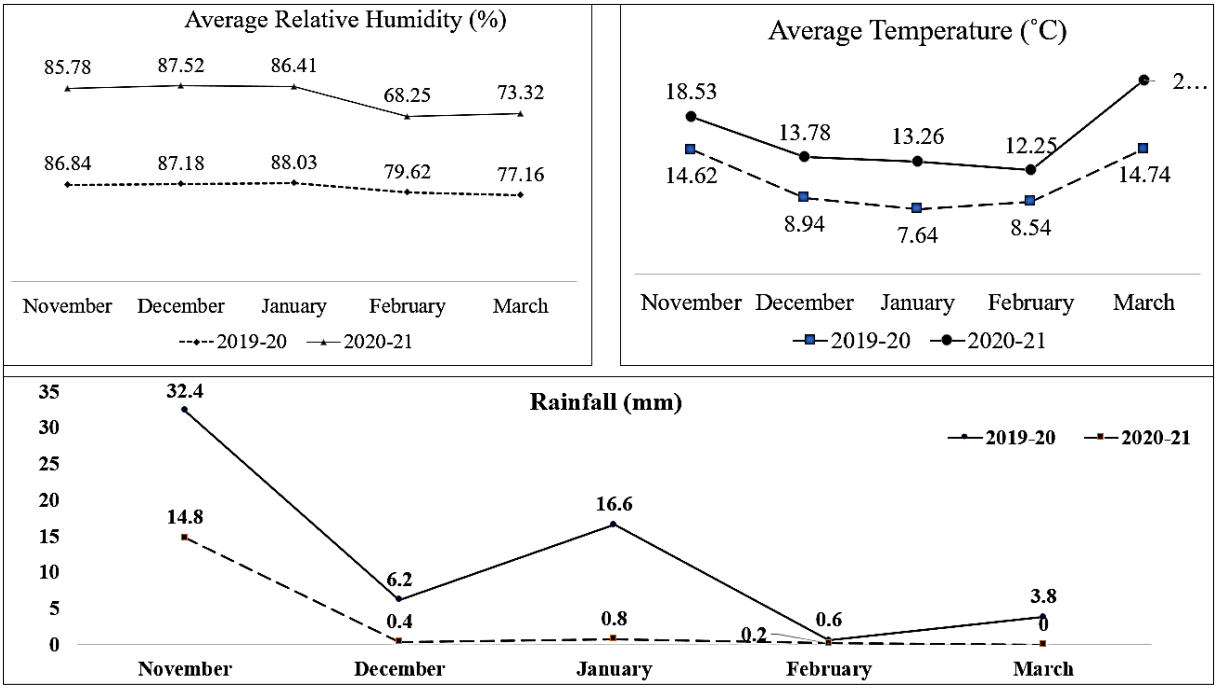


Fig 1: Monthly average air temperature, average relative humidity, and total rainfall for the trial location during 2019-20 to 2020-21.

Results and Discussion

Effect of seed rates on Ajowan

This study was undertaken to investigate the impact of different seed rates on the yield and yield-contributing traits of Ajowan. Data for seven traits were collected from the spices research sub-center, Faridpur during 2019-20 and 2020-21 and statistical analyses were conducted for probable explanations. The ANOVA of seven yield and yield-related traits of Ajowan is shown in Table 1-2.

Table 1 displays the aggregated outcomes of two consecutive seasons. This table showed significant ($p \leq 0.05$) variations among the treatments for plant height(cm), no. of branches/plant, no. of umbels/plant, and yield (kg/ha).

Plant height was found highest (108.72 cm) in the high seed rate (5.0 kg/ha) and the lowest (94.50cm) in the low seed rate (3 kg/ha). Here Plant height increased gradually as the seeding rate increased. A denser plant population produce longer plant because of the composition of the light that penetrates the plant canopy, while the light density of the plant causes the development of vegetative lateral shoots (Ball *et al*., 2000) [5]. This result aligns with other existing literature reported by Ahmed and Haque (1987) [3] and Telci (1995) [20].

Branches per plant decreased in number with the increase in plant population. The highest branch number (11.53) was obtained from the lowest density (3kg/ha). But it is statistically like other treatments except for 5kg/ha. Similarly, Kizil (2002) [12] reported that as the seed rate increased, the number of branches per plant decreased. This is probably because the high seed rate created higher interplant competition.

The highest umbel/plant (143.43) and umbellets/umbel (16.80) were observed for 4kg/ha seed rate. Seeds/umbel found highest (339.7) in the 3.5 kg/ha seed rate. 1000 seeds weight and yield (kg/ha) were recorded highest from 4.5 kg/ha seed rate plot. But 1000 seeds weight showed statistically similar results for all treatments. Yield (kg/ha) increased gradually with the increase of seed rate except for the most densely populated treatment (5kg/ha). The increases in yield with increasing seed rate applications can be explained partly by increasing the plant density in the area. It is known that it was a close relationship between seed yield and plant density. Telcill (1995) [20] also reported that seed yields were increased by increasing seed rate application. However, the yield decreases with the application of 5 kg/ha seed rate can be explained by probably decreased yield components due to excessive increasing of plant density. When the seed rate increased, plant population density increased, which might have caused greater competition for available water, nutrients, and light, thus leading to lower seed yield. (Kizil, 2002) [12].

Table 1: The combined result of different traits responded by different seed rates in 2019-20 and 2020-21

Seed rate	Plant height (cm)	Number of Branches/ plants	Number of umbel/ plants	Number of umbellets/ umbel	Number of seeds/ umbels	1000 Seeds weight (g)	Yield (kg/ha)
3 kg/ha	94.50 b	11.53 a	130.57 a	16.47	327.60	0.81	786.15 c
3.5 kg/ha	97.30 b	11.43 a	135.10 a	16.78	339.7	0.81	844.59 b
4 kg/ha	98.53 b	11.03 a	143.43 a	16.80	334.56	0.77	889.59 b
4.5 kg/ha	105.10 a	10.67 a	121.73 a	16.03	327.29	0.82	987.48 a
5 kg/ha	108.72 a	8.93 b	94.07 b	15.67	309.02	0.74	854.34 b
CV (%)	4.71	9.32	15.95	6.23	6.24	8.38	4.96
Level of Significance	***	**	**	NS	NS	NS	**

Footnote: *5% level of probability, ** 1% level of probability; *** 0.1% level of probability, NS non-significant

Table 2 presented separate data for two individual seasons of 2019-20 and 2020-21. In both seasons plant height was affected by seed rates significantly and plant height increased gradually with the increase of seed rate. The highest plant height (117.40 cm) was found in the 2020-21 season for 5 kg/ha seed rate. The highest branch number per plant (12.86) was obtained by 4.0 kg/ha seed rate in 2019-20. In 2019-20, no. umbels/plant responded significantly by different seed rates but it showed a non-significant result in 2020-21. Maximum no. of umbel/plant (179.13) achieved by 4.0 kg/ha seed rate in 2019-20 and minimum (84.33) by 5.0 kg/ha seed rate in 2020-21. no umbellets/umbel and seeds/umbel traits exhibited statistically similar results for all seed rate treatments in both years. The highest no. of umbellets/umbel (17.67) and no. of seeds/umbel (260.27) was noticed in the 2019-20 season. From the table, it is declared that bold seed was found in 2019-20 than 2020-21 season because 1000-seed weights were found better in 2019-20 than in 2020-21. 1000-seed weight remains highest (0.88g) at 4.5 kg/ha seed rate in 2019-20 and lowest (0.65 g) at 5.0 kg/ha in 2020-21 but they are insignificantly affected by different seed rates. The seed yield of Ajowan is affected significantly by different seed rates or plant populations. In consecutive two years seed yield increased successively with the increase of seed rate or plant population but at 5kg/ha seed rate, it decreased in both years. The most seed yield (1051.44 and 923.52 kg/ha) was gained by 4.5 kg/ha seed rate in 2019-20 and 2020-21 respectively.

From Table 2 discussion, it comes to light that Ajowan grow more vigorously in 2019-20 than in 2020-21. It happened most probably for environmental conditions. In 2019-20, air temperature and relative humidity was remaining less in the growing season than in 2020-21 and more rainfall occurred. So, this favorable weather condition helped to obtain better growth and yield of Ajowan in 2019-20 than in 2020-21.

Table 2: Performance of Ajowan in different seed rate in 2019-20 and 2020-21

Seed Rate (kg/ha)	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
	Plant height		No. branches/plant		No. umbel/plant		No. umbellets/umbel	
3 kg/ha	84.80 c	104.20 c	12.13 a	10.93 a	160.73 a	100.40	17.00	15.93
3.5 kg/ha	88.80 bc	105.80 bc	12.13 a	10.73 a	167.13 a	103.07	17.67	15.90
4 kg/ha	87.40 bc	109.67 b	12.87 a	9.20 ab	179.13 a	107.73	17.53	16.07
4.5 kg/ha	94.20 ab	116.00 a	12.27 a	9.07 ab	165.60 a	77.87	16.53	15.53
5 kg/ha	100.03 a	117.40 a	9.87 b	8.00 b	103.80 b	84.33	15.93	15.40
Level of sig.	**	***	*	*	**	NS	NS	NS
CV%	4.07	2.40	7.07	11.28	10.15	19.06	4.33	8.29

Table 2: Continued

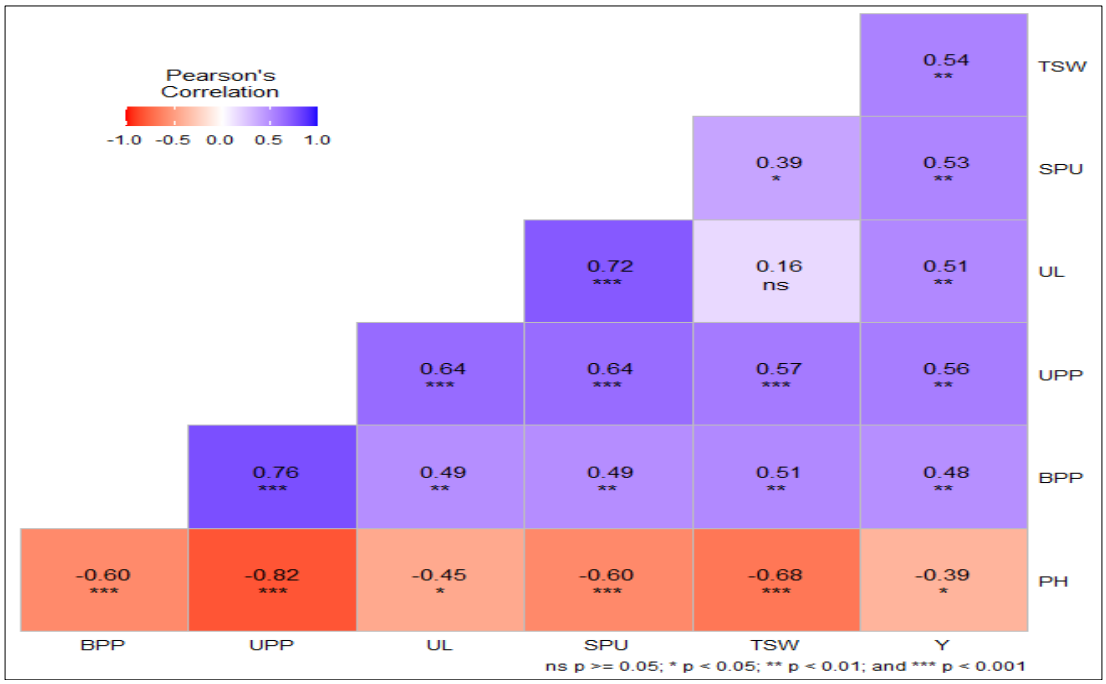
Seed Rate (kg/ha)	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
	seeds/umbel		1000-seed weight (g)		Yield (kg/ha)	
3 kg/ha	345.93	309.27	0.87	0.75	925.46 b	646.85 c
3.5 kg/ha	360.27	319.12	0.85	0.76	1018.43 a	670.74 bc
4 kg/ha	356.87	312.25	0.85	0.69	1020.62 a	758.56 b
4.5 kg/ha	345.77	308.81	0.88	0.75	1051.44 a	923.52 a
5 kg/ha	312.87	305.17	0.83	0.65 a	959.13 b	749.55 b
Level of sig.	NS	NS	NS	NS	**	**
CV%	7.94	3.54	11.50	12.335	3.13	7.21

Footnote: *5% level of probability, ** 1% level of probability; *** 0.1% level of probability, ^{NS} non-significant

Association of traits among different seed rates (Correlation coefficient and regression)

To improve crop yield or plant structure, selection must be based on related characteristics association. The statistics that measure the association between two or more variables is known as the correlation coefficient. It measures the mutual relationship between various plant characters and determines component characters on which selection can be based for improvement in seed yield. It might be easier to increase seed yield by increasing the smallest yield components on an otherwise good cultivar. The correlations were presented in Table 1. In this study, a combined correlation coefficient analysis of 2019-20 and 2020-21 years was done for six traits.

The seed yield per hectare in Ajowan is closely linked to certain agronomic traits, such as the thousand seed weight (r = 0.54**), number of branches per plant (r = 0.48**), number of umbels per plant (r = 0.56**), number of umbellets per umbel (0.51**), and number of seeds per umbel (0.53*). This suggests that increasing these traits could lead to higher seed yield, while decreasing them could result in lower yield. However, plant height (r = -0.39*) showed a negative correlation with seed yield, as did the thousand seed weight (-0.68***), number of branches per plant (r = -0.6***), number of umbels per plant (r = -0.82***), number of umbellets per umbel (-0.45*), and number of seeds per umbel (-0.6****). This finding is consistent with the results of a study by Endalkachew *et al.* in 2020 [10].



(PH= Plant height, BPP= No. of branches/plant, UPP= Umbel/plant, UL=Umbellets/umbel, SPU= Seeds/umbel, TSW= 1000-seed weight and Y= Yield)

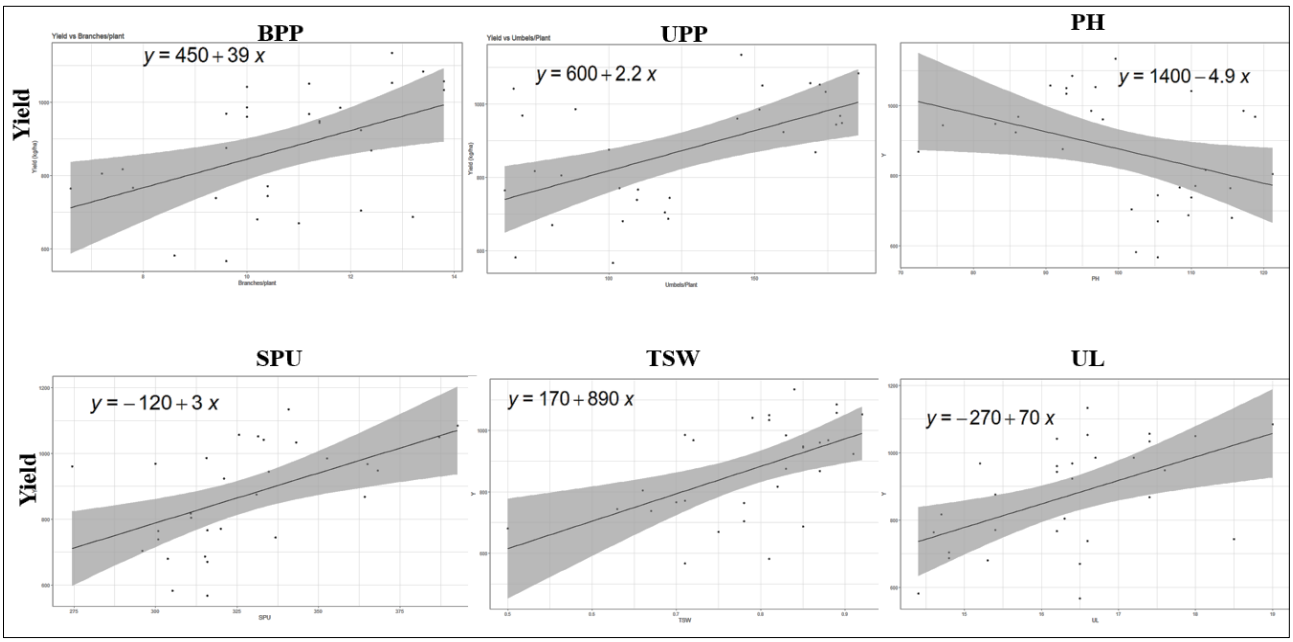
Fig 2: Association of different traits from trial

Sometimes, the correlation coefficient doesn't give a full understanding of how traits are related. Luckily, the regression coefficient can help us look deeper and determine how significant each trait is in contributing to the yield. After conducting regression analysis, we found that the thousand seed weight, number of branches per plant, number of umbels per plant, number of umbellets per umbel, and number of seeds per umbel were the most important traits for yield in Ajowan. The regression value for these traits was 0.45 (Table 3).

Table 3: Results of single-line and multiple-line regression for the studied traits of Ajowan, based on observations from two seasons: 2002-2021 and 2021-2022.

Item	SLR						MLR
	BPP	PH	SPU	TSW	UL	UPP	
b	38.99	-4.901	3.041	894.4	69.87	2.19	
R^2	0.204	0.1229	0.2527	0.2678	0.2364	0.292	0.4459
P-Value	0.007	0.03	0.003	0.002	0.004	0.001	0.002

(PH= Plant height, BPP= No. of branches/plant, UPP= Umbel/plant, UL=Umbellets/umbel, SPU= Seeds/umbel, TSW= 1000-seed weight, Y= Yield, SLR= Single linear Regression and MLR= Multiple Linear Regression)



(PH= Plant height, BPP= No. of branches/plant, UPP= Umbel/plant, UL=Umbellets/umbel, SPU= Seeds/umbel and TSW= 1000-seed weight)

Fig 3: Graph displaying contributions of different traits to the seed yield variation

Conclusion

From the above result, it is concluded that yield and yield contributing characters of Ajowan highly depended on plant population, and among the five different seed rates, maximum traits performed excellently at 4.5 kg/ ha seed rate. So, it is recommended that the 4.5 kg/ha seed rate is best for Ajowan cultivation in Bangladesh.

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