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Original Research Article

Influence of Planting Distances, Boron Application and Varying Fertilizer Levels on the yield Performance of Shallot (*Allium Cepa var. Aggregatum*) Across Season in Ilocos Norte, Philippines

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Abstract: Shallots are gaining importance in the Ilocos region, due to their culinary uses in traditional cuisine, medicinal properties, and export potential. However, the reduction of inherent soil fertility and the manifestation of multiple nutrient deficiencies have led to low yields which is 13.70% lower than the national average. Consequently, researchers and farmers are aware in the improvement of shallot production in the region. This study, conducted from March, 2023 to February, 2024, at Mariano Marcos State University using a Strip-Split-Plot design with three replicates and analyzed using STAR. Planting distances as vertical plot, boron application as horizontal plot, and fertilizer level as the subplot. The study aimed to evaluate the influence of planting distances on yield performance of shallots, and to develop better nutrient management strategies for optimal shallot production. To optimized shallot productivity per land unit area, particularly during the off-season, it is recommended to adopt closer planting distances of 15cm x 10cm combined with the application of 30-30-30 kgha^{-1} $NP_2O_5K_2O$ and 5 tha^{-1} of organic fertilizer. This technique has been shown to produce higher yields, reaching up to 17.39 tha^{-1}. Additionally, pure organic fertilizer application at a rate of 7.5 tha^{-1} during the off-season is also recommended, as it has demonstrated high yields of 16.12 tha^{-1} when using the same planting distance of 15 cm x 10 cm. This approach not only increases yield but also improves soil health, making it a sustainable option for long-term cultivation. For the regular season, planting distances of 20 cm x 10 cm and 15 cm x 15 cm, applied with 60-60-60 kg ha^{-1} $NP_2O_5K_2O$ and 2.5 tons ha^{-1} of organic fertilizer, are recommended, as they have produced yields of up to 29.4 tons ha^{-1}. While pure inorganic fertilizer results in high yields during the regular season, a combination of organic and inorganic fertilizers is preferred to enhance soil health and prevent soil degradation. Additionally, 20 cm x 20 cm planting distance is still recommended during the regular season, as it produces fewer unmarketable bulblets and larger equatorial diameter, where, it meets the consumer preferences especially for culinary purposes in traditional cuisines. The application of boron, especially in pure inorganic fertilization, shows potential in improving growth performance and yield productivity in shallot production. Therefore, further studies on boron application are recommended to optimize its benefits.

Keywords: Shallot productivity, Fertilization, Planting Distance, boron application, Ilocos Region, Season.

INTRODUCTION

Shallots, also known as *lasona* in Iloko, serve dual purposes, being valued for both their small bulbs and their leaves, which are used as condiments in salads, vegetable dishes, and various culinary applications. Their cultivation is extensive, driven primarily by culinary demands and export opportunities. Unlike other onion varieties, shallots offer a milder, more subtle flavor, making them ideal for pickling and garnishing purposes (Johnson, 2021). Notably, shallot cultivars such as Tanduyong, Australian, and Batanes are witnessing increasing demand for export (Agribusiness Promotion

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Division – Department of Agriculture [APD-DA], 2020.).

In Ilokano cuisine, one popular dish utilizing green shallots is the KBL, a classic combination of *kamatis* (tomatoes), *bagoong* (fermented fish or shrimp paste), and *lasona*, serving as a sauce for fried meats or as an appetizer. According to Grubben and Denton (2004), fresh and sliced shallots exhibit antibiotic properties that help reduce bacterial, protozoal, or helminthic contamination in salads.

In 2022, the volume of shallot production decreased to 8.52 thousand metric tons (TMT), marking a 13.2% reduction from the previous year's output of 9.81 TMT. The Ilocos Region emerged as the leading producer, contributing 8.51 TMT, which accounts for nearly 99% of the total national production. Cagayan Valley and Central Visayas followed with 1.6 TMT and 1.5 TMT, respectively (Philippine Statistics Authority [PSA], 2022).

The average yield of shallots nationwide stands at approximately 9.91 tons per hectare (tha^{-1}) (APD-DA, 2020.), falling below the Asian average yield of 13 t/ha by 23.77% and the global average yield of 17 t/ha by nearly 41.77%. Notably, Ilocos Norte's average yield remains lower than the national average at 7.44 t/ha (PSA, 2022).

Several factors contribute to this lower yield. Among them are challenges in maintaining high-quality seeds, exacerbated by complex issues like high temperatures leading to dehydration and shriveling, which can distort enzyme structures and thicken proteins due to direct cellular activity (Tekle, 2015). Additionally, shallots require specific temperature conditions during different growth stages, with lower temperatures favored during vegetative growth and higher temperatures during bulb formation and maturation (Virginia & Simon, 2012). Furthermore, inherent soil fertility reduction and the presence of multiple nutrient deficiencies contribute to imbalanced crop nutrition (Bucao *et al*., 2020).

Shallots, along with other lily crops, are particularly susceptible to nutrient absorption issues due to their shallow root systems. Thus, meticulous nutrient management, especially regarding fertilizer application, is crucial (Rizk *et al*., 2012). While NPK fertilizers are primary drivers of increased crop productivity, micronutrients play a vital role in enhancing plant metabolic processes and responses to environmental stresses (Dimkpa & Bindraban, 2016).

Boron, for instance, aids in nutrient absorption, particularly calcium and magnesium, regulates water and nutrient movement within plants, and is involved in various metabolic processes such as nucleic acid and protein synthesis (Brown *et al*., 2012). Additionally, it plays a pivotal role in shallot bulb formation, facilitating cell division and elongation necessary for bulb growth and flowering (Liakopoulos *et al*., 2015).

Soil fertility also influences disease development, both soil-borne and air-borne. Facultative pathogens thrive in environments with poor nutrient conditions, weakening the defense mechanisms of plants. Conversely, over-fertilized plants are more susceptible to certain biotrophic pathogens like rusts and powdery mildews. Soil organic matter content plays a significant role in suppressing soil-borne diseases (NTS, 2020).

Furthermore, planting distances play a crucial role in determining the yield potential per unit area. Canopy development influences the crop production system by affecting light interception for photosynthesis and the allocation of dry matter to the economic parts of specific crops. The management of the canopy of specific crops is achievable through adjustments in furrow spacing, which significantly impact plant density. As plant population increases, yield per unit area also increases until it reaches the optimum level determined by the genetic capability of the plants. Beyond this point, yield per unit area declines due to reduced yield performance per plant caused by competition for growth factors among neighboring plants (Silvertooth, 2001).

Therefore, planting distance emerges as a critical factor in shallot production as it directly influences crop yield per unit area and individual yield performance. Moreover, light and air moisture (relative humidity - RH) are significantly influenced by planting distances. Air temperatures surrounding plants are not substantially altered by population or planting method. Studies indicate that relative humidity increases with rising plant population. Microclimates are subject to change over time at which readings are taken (Colville, 1968).

Lastly, the favorable climatic conditions in the country, characterized by hot and humid climates with temperatures ranging from 21-30°C and high relative humidity (80-90%), create an environment conducive to disease development (Dimkpa *et al*., 2013). This directly impacts shallot yield performance. According to the Bureau of Agricultural Statistics (BAS) under the PSA (2022), approximately sixty percent (50.96%) of shallot growers in the country have reported pest and disease incidence. Region 1, particularly the provinces of Ilocos Norte and Ilocos Sur, is among the areas most affected by pest and disease problems.

METHODOLOGY

This study employs a quantitative research methodology to evaluate the influence of planting distance, boron application, and varying levels of organic and inorganic fertilizers. It was carried out at the research experimental area of the Mariano Marcos State University, Batac City, Ilocos Norte. The experimental site was established on March 16, 2023, for the off-season experiment, and on November 15, 2023, for the regular season setup. Situated in a rainfed lowland area, the site had previously been cultivated with pigmented rice during the wet seasons of both 2022 and 2023. Using a batanes red as the shallot variety, the study was laid out in a strip-split-plot design with three replicates. The vertical plot of the study was assigned to planting distances while the horizontal plot was assigned to the application of boron and the sub plot are the varying fertilizer levels. Each replicate was spaced of 75 cm with each main plots (vertical and horizontal) at 60 cm, respectively, and 50 cm between subplots with an area of 10 m^2 per plots.

The following treatments served as the variables of the study:

Application of Boron (Horizontal Plot)

B_1 – without Boron

B_2 – with Boron ($2Lha^{-1}$)

Planting Density (Vertical Plot)

PD_1 – 20 cm x 20 cm

PD_2 – 20 cm x 10 cm

PD_3 – 15 cm x 15 cm

PD_4 – 15 cm x 10 cm

Varying Level of Organic and Inorganic Fertilizer (Subplot)

F_1 – 90-60-60 $kgha^{-1}$ $NP_2O_5K_2O$ Pure Inorganic Fertilizer (IF)

F_2 – 60-60-60 $kgha^{-1}$ $NP_2O_5K_2O$ IF + 2.5 tha^{-1}

F_3 – 30-30-30 $kgha^{-1}$ $NP_2O_5K_2O$ + 5 tha^{-1}

F_4 – 7.5 tha^{-1}

	FieldCol1	FieldCol2	FieldCol3	FieldCol4	FieldCol5	FieldCol6	FieldCol7	FieldCol8	FieldCol9	FieldCol10	FieldCol11	FieldCol12
FieldRow1	101 PD4 B2 F4	102 PD3 B2 F2	103 PD1 B2 F4	104 PD2 B2 F3	201 PD4 B1 F3	202 PD1 B1 F3	203 PD2 B1 F3	204 PD3 B1 F2	301 PD1 B2 F3	302 PD4 B2 F4	303 PD3 B2 F3	304 PD2 B2 F1
FieldRow2	105 PD4 B2 F2	106 PD3 B2 F4	107 PD1 B2 F2	108 PD2 B2 F4	205 PD4 B1 F4	206 PD1 B1 F4	207 PD2 B1 F2	208 PD3 B1 F1	305 PD1 B2 F4	306 PD4 B2 F3	307 PD3 B2 F1	308 PD2 B2 F4
FieldRow3	109 PD4 B2 F1	110 PD3 B2 F1	111 PD1 B2 F1	112 PD2 B2 F1	209 PD4 B1 F2	210 PD1 B1 F1	211 PD2 B1 F1	212 PD3 B1 F4	309 PD1 B2 F2	310 PD4 B2 F1	311 PD3 B2 F4	312 PD2 B2 F3
FieldRow4	113 PD4 B2 F3	114 PD3 B2 F3	115 PD1 B2 F3	116 PD2 B2 F2	213 PD4 B1 F1	214 PD1 B1 F2	215 PD2 B1 F4	216 PD3 B1 F3	313 PD1 B2 F1	314 PD4 B2 F2	315 PD3 B2 F2	316 PD2 B2 F2
FieldRow5	117 PD4 B1 F1	118 PD3 B1 F1	119 PD1 B1 F4	120 PD2 B1 F3	217 PD4 B2 F1	218 PD1 B2 F1	219 PD2 B2 F2	220 PD3 B2 F2	317 PD1 B1 F3	318 PD4 B1 F2	319 PD3 B1 F3	320 PD2 B1 F1
FieldRow6	121 PD4 B1 F2	122 PD3 B1 F3	123 PD1 B1 F2	124 PD2 B1 F1	221 PD4 B2 F3	222 PD1 B2 F2	223 PD2 B2 F1	224 PD3 B2 F1	321 PD1 B1 F2	322 PD4 B1 F1	323 PD3 B1 F1	324 PD2 B1 F3
FieldRow7	125 PD4 B1 F4	126 PD3 B1 F4	127 PD1 B1 F1	128 PD2 B1 F2	225 PD4 B2 F4	226 PD1 B2 F3	227 PD2 B2 F3	228 PD3 B2 F4	325 PD1 B1 F4	326 PD4 B1 F3	327 PD3 B1 F2	328 PD2 B1 F4
FieldRow8	129 PD4 B1 F3	130 PD3 B1 F2	131 PD1 B1 F3	132 PD2 B1 F4	229 PD4 B2 F2	230 PD1 B2 F4	231 PD2 B2 F4	232 PD3 B2 F3	329 PD1 B1 F1	330 PD4 B1 F4	331 PD3 B1 F4	332 PD2 B1 F2

Figure 1: Field Lay-Out of the Study

Data Gathering Procedure

Development Stage. The main developmental phases of shallots have been meticulously documented and categorized. These phases include the bulbing stage, the flowering stage, and the maturity stage. Each of these stages plays a crucial role in the overall growth and yield of the shallot plant, contributing its characteristics and profitability profile.

Yield performance. The yield and yield components of shallot were meticulously recorded, including parameters such as the diameter of bulblets (measured both polar and equatorial), shallot weight per hill and the weight of individual bulblets. The dry yield of shallots was subsequently converted into tons per hectare to standardize the data for broader agronomic comparisons.

Profitability Analysis

The cost of production during the conduct of the study was promptly recorded. Input and output were based on prevailing market price. Profitability analysis included gross income, net income, return above variable cost (RAVC), and break-even cost.

Data Analysis

The data were arranged in table form and subjected to analysis of variance (ANOVA) for strip-split plot design using the Statistical Tool for Agricultural Research (STAR 2.0.1), a statistical software developed by the International Rice Research Institute (IRRI). Significant treatments means were further compared using Tukey's honest significant differences (HSD) test at a 5% level of probability to determine differences between or among treatment means.

RESULTS AND DISCUSSION

The results of this study revealed significant effect on the growth, yield performance and profitability of shallot as influences by the different planting distances, boron application and varying levels of organic and inorganic fertilizers. It discusses the performance of shallot on the development stages like days to bulb formation, days to maturity and percent flowering plant; yield components such as, polar and equatorial diameter, and bulblet weight; and yield converted into tons per hectare.

Days to Bulb Formation

The number of days to bulb formation in shallots was not influenced by the three factors examined: planting distances, boron application, or fertilizer levels, in either the off-season or regular season as shown in Table 3. However, earlier bulb formation was observed during the off-season, occurring at 35-36 days after planting (DAP), compared to 46-48 DAP during the regular season. This early bulb formation in the off-season aligns with the findings of Lancaster *et al*., (2006), where onions, including shallots, are significantly affected by photoperiod and temperature. According to their research, higher temperatures and longer daylight hours favor bulb development over vegetative growth.

During the off-season from March to May 2023, temperatures ranged from 31°C to 36°C, whereas during the regular season from November 2023 to January 2024, temperatures were slightly lower, ranging from 29°C to 31°C.

Percent Flowering Plants

During the off-season planting, no flowering shallots were recorded due to the effects of daylength and temperature, whereas flowering was observed during the regular planting season (Table 3). Notably, during regular planting (November to January), the average minimum temperature was 20°C, occasionally dropping to 13°C. Krontal *et al*., (2000) observed that temperatures as low as 10°C can induce flower development in shallots. Thus, the weather conditions during regular planting significantly favored flower development in shallots.

Additionally, planting distances had a significant effect on flower development. Shallots planted at 20 cm x 20 cm and 15 cm x 15 cm spacings had higher percentages of flowering plants, with 9.12% and 8.92%, respectively, compared to 20 cm x 10 cm (7.22%) and 15 cm x 10 cm (8.01%). These results indicate that plant population is inversely proportional to the percentage of flowering shallots where higher plant populations resulted in lower flower development. It was also noted that boron application, fertilizer level, and their interactions had no significant effects on shallot flower development.

Days to Maturity

During the off-season planting, the maturity of shallots was not affected by any of the factors used or their interactions. Generally, the shallots matured at 49 DAP (Table 3), which can be attributed to the daylength and high temperature experienced from March to May. In contrast, the maturity of shallots planted during the regular season was influenced by the three factors and their interactions. Results showed that shallots matured between 67 and 74 DAP. As shown in Figure 3, longer days to maturity were observed in wider planting distances with the application of boron, while test plots without boron application and with a planting distance of 15 cm x 10 cm matured the earliest at 62-65 DAP. Generally, shallot plants without boron and with lower fertilizer rates matured faster than those that received boron and higher fertilizer rates. Thangsamay (2016) noted that excessive nitrogen application tends to produce succulent plants that are more susceptible to disease and prone to producing flower stalks. He added that heavy nitrogen fertilization delays maturity, causes double centers, and worsens the storage properties of the bulbs.

Table 3: Days to bulbing, percent flowering plants, and days to maturity of shallot as affected by different planting distances, boron application, and varying fertilizer levels across seasons

TREATMENT	Days to Bulbing				Flowering Plants (%)		Days to Maturity			
	Off -season		Regular season		Regular season		Off -season		Regular season	
Planting Distance (PD)	ns		ns		**		ns		**	
20 x 20	36		47		9.12	a	50		74	a
20 x 10	35		46		8.01	b	49		67	c
15 x 15	35		47		8.92	a	49		70	b
15 x 10	35		48		7.22	b	49		67	c
Boron (B)	ns		ns		ns		ns		*	
Without boron	35		48		8.31		49		68	b
With boron	35		46		8.33		49		71	a

Fertilizer Level (F)	ns		ns		ns		ns		**	
90-60-60	35		47		8.13		49		70	a
60-60-60+2.5tha^{-1}	35		47		7.96		49		68	b
30-30-30 + 5 tha^{-1}	35		47		9.64		49		70	a
7.5 tha^{-1}	35		47		7.53		49		69	ab
PD x B	ns		ns		ns		ns		**	
PD x F	ns		ns		ns		ns		**	
B x F	ns		ns		ns		ns		**	
PD x B x F	ns		ns		ns		ns		**	
CV (a) %	9.64		5.10		15.13		6.09		2.27	
CV(b) %	2.77		6.34		9.97		1.91		3.12	
CV (c) %	2.87		3.52		15.96		2.34		2.10	
CV (d) %	3.62		6.32		10.54		2.56		2.10	

CV = coefficient of variation
ns = not significant
* = significant at 5% level
** = significant at 1 % level
Means marked with the same letter within each column are not significantly different at 5% level using honestly significance differences

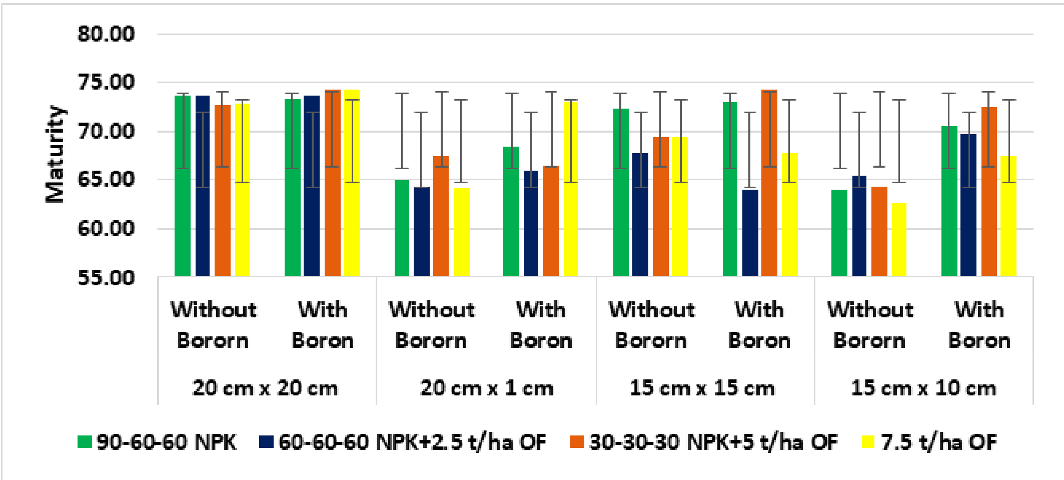

Figure 3: Interaction Effect between Planting Distances, Boron Application, and Varying Fertilizer Level on the Days to Maturity of Shallot during Regular Planting Season

Bulblet Diameter

Table 4 displays the shallot bulblet diameter. During the off-season, the bulblet appearance is primarily globular due to the similar size of the polar and equitorial diameters, whereas during the regular season, the bulblet appearance is flattened because the equitorial diameter is greater than the polar diameter.

Shallot plants had an average polar diameter of 2.18 cm during off-season planting, and ranging from 2.11 cm to 2.25 cm. whereas 2.85 cm during regular planting and ranging from 2.81 cm to 2.95 cm. Polar diameter significantly affected by planting distance during regular planting season, result show that wider spaces 20 cm x 20 cm have larger polar diameter with 2.95 cm compare to closer distance with 2.78 cm.

Comparisons across season expressed that equitorial diameter of shallot was larger during regular season with 3.29 cm compare during the off season with 2.16 cm. and it ranges from 2.10cm to 2.26 cm. Analysis of variance revealed that planting distance (PD) and the interaction between PD, B, and F during regular planting season affect the equatorial diameter of shallot.

Result revealed that the largest equitorial diameter were observed on the test plants treated with boron with planting distance 20 cm x 20 cm with a fertilizer levels of 90-60-60 kgha^{-1} $NP_2O_5K_2O$ (3.57 cm) and 30-30-30 kgha^{-1} $NP_2O_5K_2O$ + 2.5 tha^{-1} OF (3.55 cm) The smallest equitorial diameter were observed on the test plants treated without boron under 15 cm x 15 cm applied with 30-30-30 kgha^{-1} $NP_2O_5K_2O$ + 2.5 tha^{-1} OF (2.7 cm) and 30-30-30 kgha^{-1} $NP_2O_5K_2O$ + 2.5 tha^{-1} OF (2.99 cm). The same resultconducted by Sopha (2017) that planting distance have significant effect on the equitorial diameter of shallot wherein, wider spaces have larger equitorial diameter and closer distances tend to have smaller in size. It explains that they compete for resources such as precipitation, nutrients, and solar radiation that necessary for carbohydrates formation.

Table 4: Bulblet diameter-polar and equatorial (cm) on the yield performance of shallot as affected by different planting distances, application of boron, and varying fertilizer level across season

TREATMENT	Polar Diameter				Equitorial Diameter			
	Off-Season		Regular Season		Off-Season		Regular Season	
Planting Distance (PD)	ns		*		ns		**	
20 X 20	2.25		2.95	a	2.26		3.49	a
20 X 10	2.19		2.79	bc	2.18		3.20	c
15 X 15	2.14		2.88	ab	2.12		3.36	ab
15 X 10	2.15		2.78	c	2.10		3.09	c
Boron (B)	ns		ns		ns		Ns	
Without Boron	2.18		2.84		2.19		3.27	
With Boron	2.19		2.86		2.13		3.30	
Fertilizer Level (F)	ns		ns		ns		Ns	
90-60-60	2.21		2.88		2.13		3.31	
60-60-60 + 2.5 tha^{-1}	2.20		2.87		2.20		3.30	
30-30-30 + 5 tha^{-1}	2.11		2.85		2.10		3.27	
7.5 tha^{-1}	2.21		2.81		2.22		3.27	
PD x B	ns		ns		ns		Ns	
PD x F	ns		ns		ns		Ns	
B x F	ns		ns		ns		Ns	
PD x B x F	ns		ns		ns		*	
CV (a) %	7.35		5.11		11.27		5.93	
CV (b) %	13.81		4.33		11.39		8.79	
CV (c) %	8.12		3.35		8.29		2.81	
CV (d) %	6.91		3.92		8.73		3.93	

CV = Coefficient of Variation
ns = not significant
* = significant at 5% level
** = significant at 1 % level
Means marked with the same letter within each column are not significantly different at 5% level using honestly significance differences

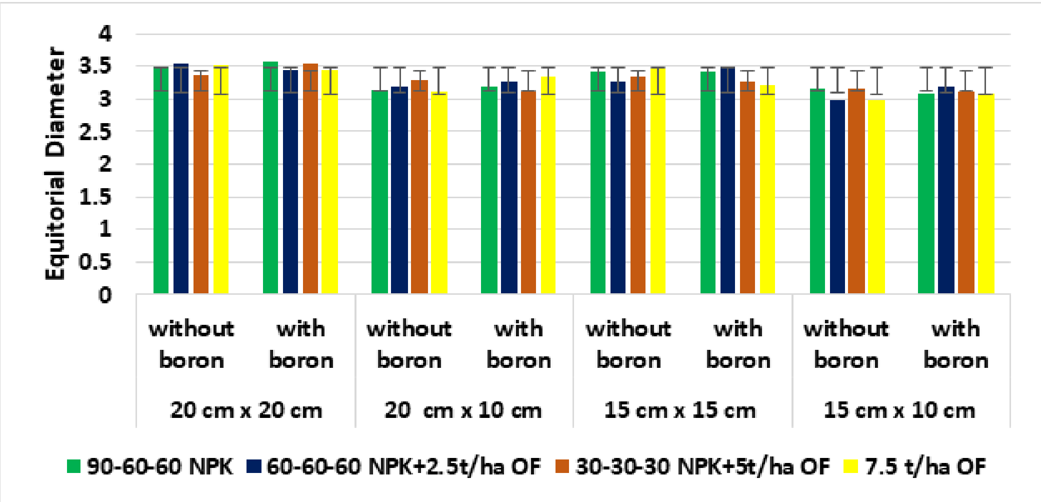

Figure 4: Interaction effect between planting distances, application of boron, and varying fertilizer level on the equitorial diameter of shallot during regular planting season

Weight Bulblet $^{-1}$ (g)

The weight of bulblets per hill during off-season planting was not significantly affected by boron (B), but it was influenced by planting distance (PD), fertilizer level (F), and all their interactions shown in Table 5. Results show that plots spaced at 20 cm x 20 cm and fertilized with 60-60-60 kgha^{-1} $NP_2O_5K_2O$ + 2.5 tha^{-1} organic fertilizer (OF) without boron, and 7.5 tha^{-1} OF with boron, produced the heaviest bulblets, weighing 12.33 g. It corroborates Rosmiah's (2024) study, which found that organic fertilizers are essential for increasing onion bulb weight. It was claimed that applying organic fertilizers, such as vermicompost, can greatly enhance the weight of onion bulbs. Certain organic fertilizers have natural growth hormones in them, or they can encourage the synthesis of plant hormones, such as gibberellins, auxins, and cytokinins. These hormones contribute to larger bulbs by being essential for cell proliferation, elongation, and general plant growth. This was followed by plots spaced at 20 cm x 10 cm and fertilized with 7.5 tha-^{1} OF without boron, yielding 12.30 g. In general, the heaviest bulblets were observed in plots spaced at 20 cm x 20 cm with boron, with weights ranging from 9.83 g (30-30-30 kgha^{-1} $NP_2O_5K_2O$ + 5.0 tha^{-1} OF) to 12.33 g (7.5 t ha-1 OF). Similarly, plots spaced at 20 cm x 10 cm without boron produced bulblets weighing between 8.63 g (90-60-60 kgha^{-1} $NP_2O_5K_2O$) and 12.30 g (7.5 tha^{-1} OF), respectively. The same finding with the study of Saurabh (2017) that wider spacing in onion cultivation results in heavier individual bulbs, with the weight of individual bulbs increasing with wider spacing, as indicated in the study that wider spacing between shallot plants reduces competition for essential resources such as light, water, and nutrients. Each plant has more access to these resources, which supports better growth and development of the bulbs. In addition, with more space, shallot plants can develop more extensive root systems. A larger root system enables the plants to absorb water and nutrients more efficiently, supporting the growth of larger bulbs.

Table 5: Weight bulblet $^{-1}$(g) and weight hill^{-1}(g) of shallot as affected by different planting distances, boron application, and varying fertilizer levels across seasons

TREATMENT	**Weight Bulblet $^{-1}$ (g)**				**Shallot Weight Hill^{-1} (g)**			
	Off-Season		**Regular Season**		**Off-Season**		**Regular Season**	
Planting Distance (PD)	**		**		**		**	
20 x 20	10.12	a	26.43	a	35.59	a	130.29	a
20 x 10	9.71	b	20.45	c	35.33	ab	79.77	c
15 x 15	8.74	c	23.37	b	35.28	ab	88.78	b
15 x 10	8.59	c	20.44	c	29.55	b	73.37	d
Boron (B)	ns		ns		ns		*	
Without boron	9.26		23.15		33.77		90.92	b
With boron	9.32		22.20		34.11		95.18	a
Fertilizer Level (F)	**		**		**		**	
90-60-60	8.92	b	23.39	a	32.58	b	100.65	a
60-60-60+2.5 tha^{-1}	9.69	a	22.64	ab	35.85	a	93.95	b
30-30-30+5 tha^{-1}	9.02	ab	22.79	ab	32.17	b	92.61	b
7.5 tha^{-1}	9.54	a	21.86	b	35.15	a	84.99	c
PD x B	**		**		**		**	
PD x F	**		**		**		**	
B x F	**		**		**		Ns	
PD x B x F	**		**		**		**	
CV (a) %	6.16		7.92		3.99		4.16	
CV(b) %	2.05		6.75		1.49		5.16	
CV (c) %	3.52		4.53		3.59		4.69	
CV (d) %	4.79		5.15		4.93		5.33	

CV = coefficient of variation
ns = not significant
* = significant at 5% level
** = significant at 1 % level
Means marked with the same letter within each column are not significantly different at 5% level using honestly significance differences

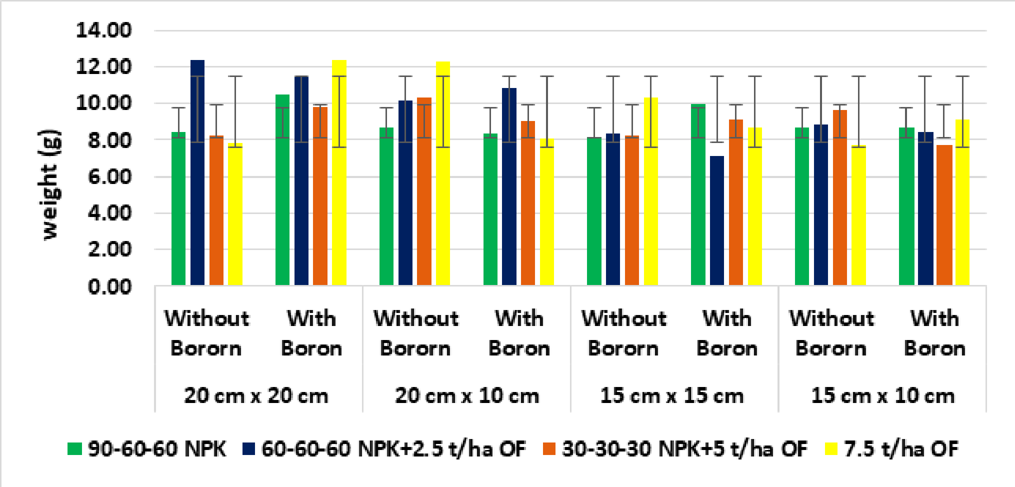

Figure 6: Interaction Effect between Planting Distances, Boron Application, and Varying Fertilizer Level on the Bulblet Weight of Shallot during Off-Season Planting

During the regular season, the average weight per bulblet was significantly influenced by PD, FL, and all their interactions (Table 5). The heaviest bulblets were observed in plots spaced at 20 cm x 20 cm without boron, with weights ranging from 25.77 g (30-30-30 $kgha^{-1}$ $NP_2O_5K_2O$ + 5.0 tha^{-1} OF) to 28.00 g (60-60-60 $kgha^{-1}$ $NP_2O_5K_2O$ + 5.0 t ha-1 OF). With boron, the weights ranged from 23.17 g (7.5 t ha^{-1} OF) to 27.90 g (60-60-60 $kgha^{-1}$ $NP_2O_5K_2O$ + 2.5 t ha^{-1} OF).

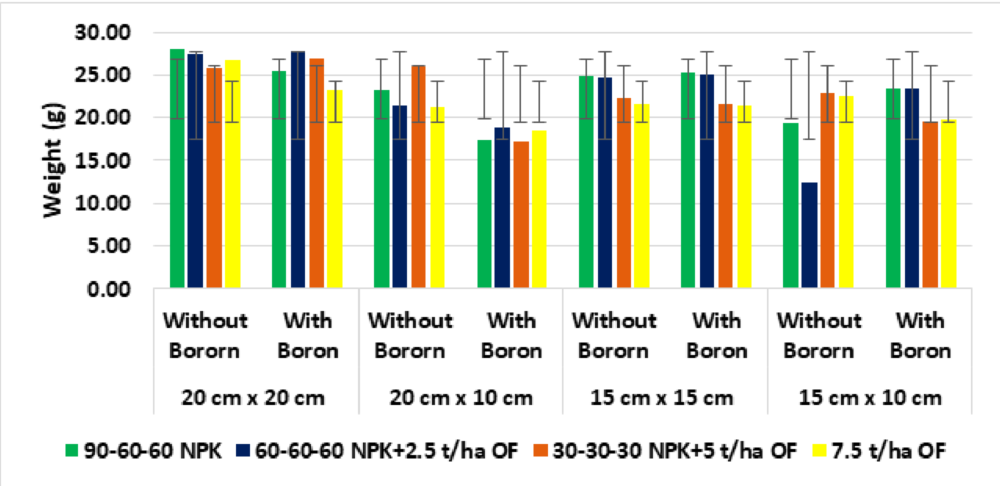

Figure 7: Interaction Effect between Planting Distances, Boron Application, and Varying Fertilizer Level on the Bulblet Weight of Shallot during Regular Planting Season

Shallot Weight $Hill^{-1}$ (g)

During the off-season planting, only the boron (B) factor did not affect the weight of bulblets per hill. All other factors, including their interactions, significantly influenced the weight of bulblets per hill (Table 6). In the PD x B x F interaction, the heaviest bulblets per hill were observed in plots spaced at 20 cm x 10 cm, treated with 60-60-60 $kgha^{-1}$ $NP_2O_5K_2O$ + 5.0 t ha^{-1} organic fertilizer (OF) and boron, yielding 47.50 g. This was followed by plots treated with 60-60-60 $kgha^{-1}$ $NP_2O_5K_2O$ + 2.5 t ha^{-1} OF and boron, spaced at 20 cm x 20 cm, yielding 42.87 g, and plots treated with 60-60-60 $kgha^{-1}$ $NP_2O_5K_2O$ + 2.5 t ha^{-1} OF without boron, spaced at 15 cm x 15 cm, yielding 41.80 g. Generally, shallots planted at 20 cm x 20 cm with boron achieved the heaviest average bulblet weight per hill at 37.10 g, regardless of the fertilizer level applied. This was followed by shallots spaced at 15 cm x 15 cm without boron, with an average weight of 36 g.

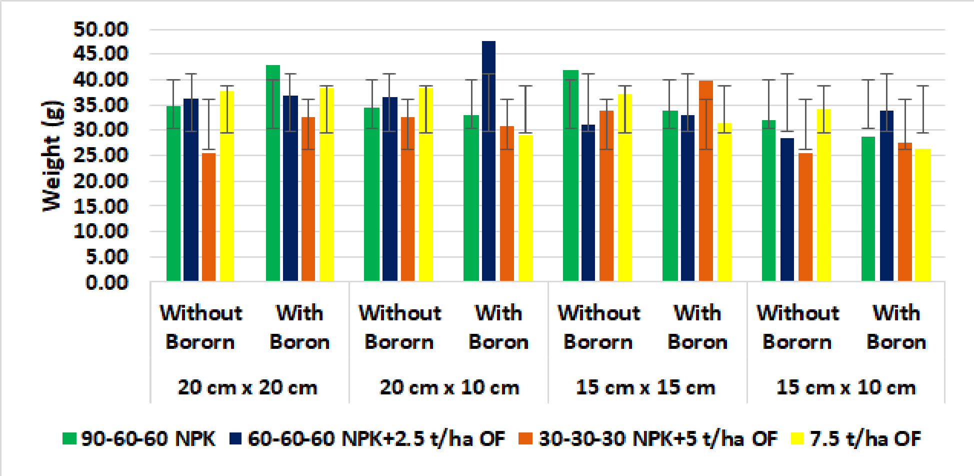

Figure 8: Interaction Effect between Planting Distances, Boron Application, and Varying Fertilizer Level on the Weight of Bulblets per Hill of Shallot during Off-Season Planting

During the regular planting season, all factors, including their interactions, significantly influenced the weight of bulblets per hill (Table 5). Results shown in Fig. 9 show that shallots planted at 20 cm x 20 cm, applied with different fertilizer levels, obtained the heaviest average bulblet weight per hill: 135.63 g when treated with boron and 124.92 g without boron. This was followed by shallots planted at 15 cm x 15 cm without boron, yielding 89.42 g, and with boron, yielding 88.13 g. These results imply that shallots planted with wider spacing tend to produce larger bulbs, especially during the regular season. There was a 233% increase in bulblet weight for shallots planted during the regular season compared to those planted during the off-season which were significantly affected by planting distance (PD), boron application (B), and the interaction between PD and B.

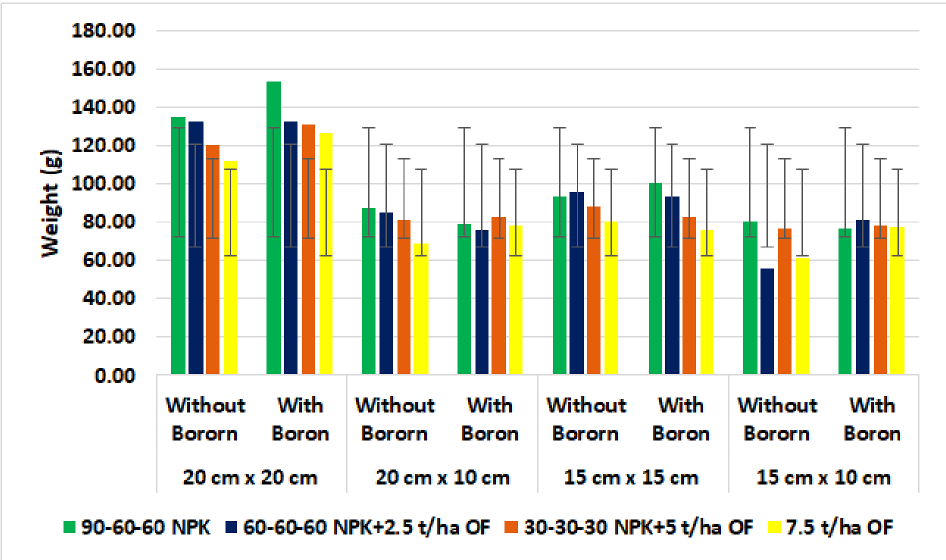

Figure 9: Interaction Effect between Planting Distances, Boron Application, and Varying Fertilizer Level on the Weight of Bulblet per Hill of Shallot during Regular Planting Season

Yield (tha^{-1})

Estimated yield of shallot are converted into tons per hectare as shown in Table 6. Yield of shallot during regular season averaged to 23.54 tha^{-1} which was higher as compared to the off-season planting with an 11.15 tha^{-1} dry weight.

During the off-season planting, yield was significantly influenced by the two main factors, planting distance (PD) and fertilizer (F), as well as all their interactions. The PD x B x F interactions revealed that the highest yield of shallots per hectare was obtained from plots spaced at 15 cm x 10 cm and fertilized with 30-30-30 $kgha^{-1}$ $NP_2O_5K_2O$ + 5.0 t ha^{-1} organic fertilizer (OF), yielding 17.39 t. interesting result showed that closer distances have higher yield compare to wider distances. It supports the findings of Wanlu (2023) that canopy shading can effectively reduce heat stress in crops like shallots by providing a cooler microclimate. Studies have shown that shading, can significantly lower air temperature, mean radiant temperature, and physiological equivalent temperature, thus reducing thermal stress that validates Khokar's (2017) study, which found that temperature affects bulb size and maturity prediction during the onion bulbing process, where extremely high or low temperatures can have a detrimental effect on shallot production

The lowest yields were observed in plots spaced at 20 cm x 20 cm and applied with 30-30-30 kgha^{-1} $NP_2O_5K_2O$ + 5.0 tha^{-1} OF, with yields of 5.72 tha^{-1} (with boron) and 5.90 tha^{-1} (without Boron). These low yields were attributed to the high temperatures and relative humidity observed throughout the off-season growing period.

Table 6: Estimated yield (tha^{-1}) of shallot as affected by different planting distances, boron application, and varying fertilizer levels across seasons

TREATMENT	YIELD (tha^{-1})			
	Off-Season		Regular Season	
Planting Distance (PD)	**		**	
20 x 20	6.68	d	23.67	b
20 x 10	12.93	b	23.03	b
15 x 15	10.54	c	24.95	a
15 x 10	14.46	a	22.53	c
Boron (B)	ns		Ns	
Without boron	11.32		24.12	
With boron	10.99		22.96	
Fertilizer Level (F)	**		**	
90-60-60	10.59	b	23.78	b
60-60-60+2.5 tha^{-1}	11.34	a	25.79	a
30-30-30+5 tha^{-1}	11.04	ab	23.47	b
7.5 tha^{-1}	11.64	a	21.13	c
PD x B	**		**	
PD x F	**		**	
B x F	**		**	
PD x B x F	**		**	
CV (a) %	8.83		7.48	
CV (b) %	8.64		8.69	
CV (c) %	7.38		5.60	
CV (d) %	6.54		4.78	

CV = coefficient of variation
ns = not significant
* = significant at 5% level
** = significant at 1 % level
Means marked with the same letter within each column are not significantly different at 5% level using honestly significance differences

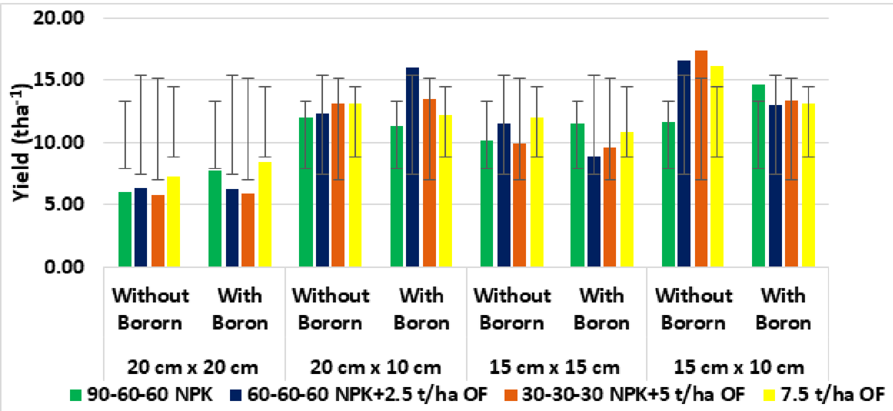

Figure 10: Interaction Effect between Planting Distances, Boron Application, and Varying Fertilizer Level on the Estimated Yield (tha^{-1}) of Shallot during Off-Season Planting

Similar trends were observed during the regular planting season, where PD and F, along with all their interactions, significantly affected yield (Table 6). However, Figure 11 shows that, unlike during the off-season planting, shallots spaced at 20 cm x 10 cm and applied with 60-60-60 kgha^{-1} $NP_2O_5K_2O$ + 2.5 tha^{-1} OF, both with and without B, achieved high yields of 29.40 tha^{-1}. This was followed by plots spaced at 15 cm x 15 cm and fertilized with 90-60-60 kgha^{-1} $NP_2O_5K_2O$ + B (29.0 t ha^{-1}) and 60-60-60 kgha^{-1} $NP_2O_5K_2O$ + 2.5 t ha^{-1} OF + B (28.60 t ha^{-1}).

Generally, shallots fertilized with 60-60-60 kgha^{-1} $NP_2O_5K_2O$ + 2.5 t ha^{-1} OF, regardless of planting distances and boron application, achieved the highest yields, ranging from 23.60 t ha^{-1} to 29.40 t ha^{-1}. The lowest yields were observed in plots applied with 7.5 t ha^{-1} OF, ranging from 20.23 tha^{-1} to 23.0 tha^{-1}. These results indicate that applying pure OF alone at 7.5 t ha^{-1} is insufficient to sustain high shallot yields. Further evaluation on the dynamics of OF application is necessary to determine the optimal quantity and timing to maximize yields.

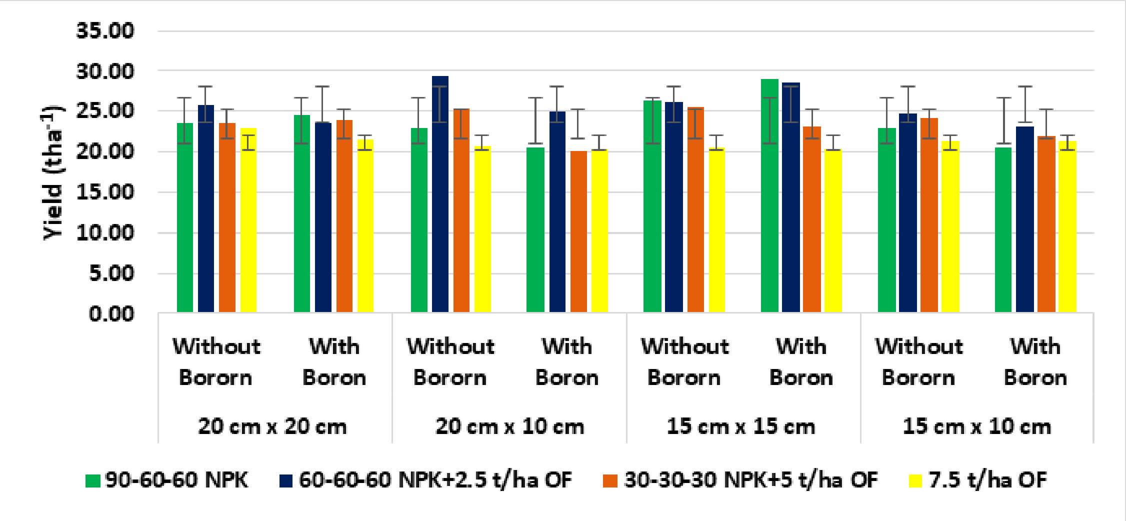

Figure 11: Interaction Effect between Planting Distances, Boron Application, and Varying Fertilizer Level on the Estimated Yield (tha^{-1}) of Shallot during Regular Planting Season

Percent Unmarketable Size

The percent unmarketable bulblets of shallot as affected by planting distance, application of boron and varying fertilizer levels are shown in Table 20. Wherein significant interaction effect between planting distance and varying fertilizer level significantly affects the percent unmarketable bulblets during off season. On the other hand, planting distance, varying fertilizer level and the interaction between planting distance, application of boron and varying fertilizer level significantly affect the percent unmarketable bulblet of shallot.

Table 20: Percent unmarketable sizes of shallot as affected by different planting distances, application of boron, and varying fertilizer level across season

TREATMENT	UNMARKETABLE SIZES (%)			
	Off Season		**Regular Season**	
Planting Distance (PD)	ns		**	
20 X 20	18.41		4.38	c
20 X 10	19.41		7.63	a
15 X 15	24.28		5.59	b
15 X 10	23.31		8.90	a
Boron (B)	ns		ns	
Without Boron	21.30		6.80	
With Boron	21.30		6.70	
Fertilizer Level (F)	ns		**	
90-60-60	20.22		6.21	b
60-60-60 + 2.5 tha^{-1}	21.53		6.45	b
30-30-30 + 5 tha^{-1}	23.09		5.59	c
7.5 tha^{-1}	20.57		8.26	a
PD X B	ns		ns	
PD X F	ns		**	

BX F	*	*
PD X B X F	ns	**
CV (a) %	24.71	22.75
CV (b) %	13.97	22.46
CV (c) %	17.01	21.71
CV (d) %	26.50	13.23
CV = Coefficient of Variation		
ns = not significant		
* = significant at 5% level		
** = significant at 1 % level		
Means marked with the same letter within each column are not significantly different at 5% level using honestly significance differences		

Furthermore, comparison between season shows significant differences were in percent unmarketable bulblet are plenty during off season with 21.35% compare during regular season with 6.63%.

Interaction effect between application of boron and varying fertilizer on percent unmarketable bulblet of shallot during off season are showed in Figure 12. Result revealed that test plots without boron with 30-30-30 NPK combined with 5 tons per hectare of organic fertilizer (OF) counted a plenty of unmarketable bulblets with 25.35%. While the least unmarketable bulblets were counted on the test plots treated with boron applied with 90-60-60 NPK and 7.5 tha^{-1} of OF with 18.67% and 18.69%, respectively.

Interestingly, the results indicate that applying boron during the off-season can significantly reduce the percentage of unmarketable sizes in crops fertilized with both pure organic and pure inorganic fertilizers. This finding aligns with the study of Shahid *et al*., (2018), which demonstrated that boron application reduces the occurrence of unmarketable bulblets in shallots, particularly under high-temperature conditions.

Elevated temperatures can negatively affect bulb quality and formation. Boron, in this context, plays a key role in stabilizing cell membranes and facilitating sugar mobilization, both of which are critical for maintaining plant health under stressful environmental conditions. Moreover, Woldetsadik & Workneh (2010) also found that boron application enhances the overall quality of shallots by promoting more robust growth and mitigating the detrimental effects of high temperatures. This makes boron a valuable nutrient for improving both the marketability and resilience of shallots, especially in regions or seasons prone to heat stress

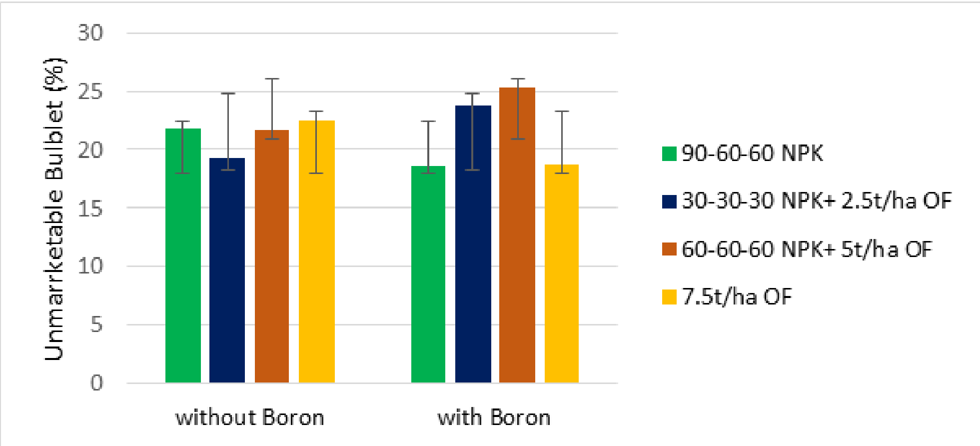

Figure 12: Interaction effect between application of boron and varying fertilizer on percent un marketable bulblet of shallot for off season of planting

Lastly, Significant interaction effect between planting distances, application of boron, and varying fertilizer level on percent unmarketable bulblets of shallot for regular season were showed on Figure 13. A notable observation in the test plot treated with boron at a planting distance of 15 cm x 10 cm, combined with the application of 7.5 tons per hectare of organic fertilizer (OF), is the relatively high percentage of unmarketable bulblets, recorded at 17.22%. During the regular season, the findings are contrarily to the results during the off season and to the study of Siahaan (2015), who reported that the application of boron significantly reduced the percentage of unmarketable shallot bulblets. In Siahaan's study, boron was found to play a crucial role in improving the quality of shallot bulbs by enhancing nutrient uptake, particularly calcium and potassium, both of which are essential for the formation of strong, marketable bulbs. However, in the current experiment, the higher incidence of unmarketable bulblets suggests that the boron treatment, combined with the specific planting density and organic fertilizer rate used, did not have the expected positive impact on bulb quality.

Several factors could explain this discrepancy. The rate of organic fertilizer applied might have interacted with boron in ways that diminished its efficacy, either through nutrient imbalances or altered soil chemistry. It's also possible that differences in environmental conditions, such as soil type, moisture levels, or temperature, between the current study and Siahaan's research contributed to the contrasting results. Thus, further investigation is necessary to determine whether adjusting the planting density, fertilizer rates, or boron application methods could optimize bulb quality and reduce the percentage of unmarketable bulblets in future trials. Understanding the interaction between boron and other agronomic factors in shallot production is crucial for improving crop outcomes and ensuring consistency in bulb marketability

The lowest percentages of unmarketable shallot sizes were observed in the test plots without boron, specifically at a planting distance of 20 cm x 20 cm. The fertilizer treatments of 30-30-30 NPK combined with 5 tons per hectare of organic fertilizer (OF) resulted in 2.20% unmarketable bulbs, while the 60-60-60 NPK plus 2.5 tons per hectare of OF treatment led to 3.24% unmarketable sizes. This supports the findings of Purba (2016), who demonstrated that the right combination of inorganic and organic fertilizers not only improves bulb size but also enhances the overall profitability of shallot production. Additionally, Afifati (2022) emphasized that optimal planting distances can reduce the percentage of unmarketable shallot sizes, reinforcing the importance of proper spacing in improving bulb quality.It explains that the wider spacing between plants likely reduces competition for nutrients, water, and sunlight, allowing each plant to develop more robustly, leading to a higher proportion of marketable bulbs.

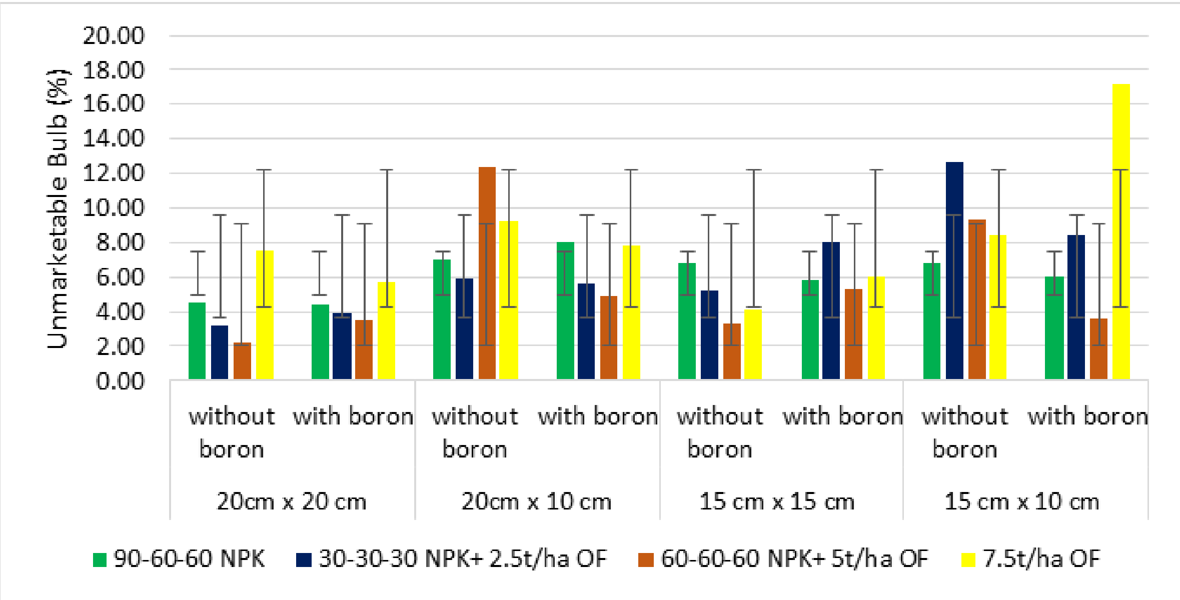

Figure 13: Interaction effect between planting distances, application of boron, and varying fertilizer level on percent unmarketable bulblets of shallot for regular season of planting

CONCLUSIONS

Based on the result of the study, the researcher came up with the following conclusions:

There was an influence of planting distance on the yield performance of shallot across season, where 15cm x 10cm have performed better during off-season with 14.46 tha^{-1}, while 15cm x 15cm recorded the highest yield during regular planting season with 24.95 tha^{-1}.

There was an effect of varying fertilizer level on the yield performance of shallot wherein during off-season, shallot plants applied with 7.5 tha^{-1} of pure organic fertilizer dominated its performance with 11.64 tha^{-1}, while 60-60-60 $kgha^{-1}$ $NP_2O_5K_2O$ + 2.5 tha^{-1} organic fertilizer have better performance during the regular season of planting with 25.79 tha^{-1}.

There was an interaction effect of planting distance, application of boron, and varying fertilizer level on the yield performance of shallot wherein the highest yielder during off-season was recorded on the test plots without boron application under 15cm x 10cm applied with 30-30-30 $kgha^{-1}$ $NP_2O_5K_2O$ + 5 tha^{-1} organic fertilizer, 60-60-60 $kgha^{-1}$ $NP_2O_5K_2O$ + 2.5 tha^{-1} organic fertilizer and 7.5 tha^{-1} pure organic fertilizer with 17.39 tha^{-1}, 16.56 tha^{-1} and 16.12 tha^{-1}, respectively, while the highest yielder during the regular season was recorded on the test plants without boron application under 20 cm x 10cm with a fertilizer levels of 60-60-60 $kgha^{-1}$ $NP_2O_5K_2O$ + 2.5 tha^{-1} organic fertilizer with 29.40 tha^{-1}, and under 15cm x 15cm treated with boron with fertilizer levels of 90-60-60 $kgha^{-1}$ $NP_2O_5K_2O$ and 60-60-60 $kgha^{-1}$ $NP_2O_5K_2O$ + 2.5 tha^{-1} organic fertilizer with 29.00 tha^{-1} and 28.60 tha^{-1}.

Recommendations

Based on the result of the study and to the conclusion made, the researcher recommends the following:

To enhance shallot production, particularly during the off-season, it is recommended to adopt closer planting distances of 15 cm x 10 cm combined with the application of 30-30-30 kg ha^{-1} $NP_2O_5K_2O$ and 5 tons ha^{-1} of organic fertilizer. This technique has been shown to produce higher yields, reaching up to 17.39 tons ha^{-1}. Additionally, pure organic fertilizer application at a rate of 7.5 tons ha^{-1} during the off-season is also recommended, as it has demonstrated high yields of 16.12 tons ha^{-1} when using the same closer planting distance of 15 cm x 10 cm. This approach not only increases yield but also improves soil health, making it a sustainable option for long-term cultivation.

For the regular season, planting distances of 20 cm x 10 cm and 15 cm x 15 cm, applied with 60-60-60 kg ha^{-1} $NP_2O_5K_2O$ and 2.5 tons ha^{-1} of organic fertilizer, are recommended, as they have produced yields of up to 29.4 tons ha^{-1}. While pure inorganic fertilizer results in high yields during the regular season, a combination of organic and inorganic fertilizers is preferred to enhance soil health and prevent soil degradation. Additionally, 20 cm x 20 cm planting distance is still recommended during the regular season, as it produces fewer unmarketable bulblets and larger equatorial diameter, where, it meets the consumer preferences for high-quality produce.

The application of boron, especially in pure inorganic fertilization, shows potential in improving growth performance and yield productivity in shallot production. Therefore, further studies on boron application are recommended to optimize its benefits.

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