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Determination of Optimal Balanced Fertilizer Rate and Irrigation Scheduling for Onion under Vertisol Soil Type

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Abstract
The onion is one of the vegetable crops grown under irrigation. In order to improve crop production and productivity, irrigation is the only solution for contributing to food security, self-sufficiency, and the export market. The experiment was conducted at Debre Zeit Agricultural Research Center with the determination of the optimally balanced fertilizer rate and irrigation scheduling for onions under Vertisol soil type to determine the optimum rate of balanced fertilizers and irrigation intervals and identify the interactive effect of nutrient and moisture levels on the yield and yield quality of onion.The experimental treatments had three irrigation intervals, viz., 80% MAD, 100% MAD, and 120% MAD, and three fertilizer rates of application, viz., 100 kg ha^{-1} NPSB, 150 kg ha^{-1} NPSB, and 200 kg ha^{-1}, and a control fertilizer rate of 100 kg ha^{-1} urea. The design of the experimental plot was split into the RCBD arrangement. The experimental study result showed that Crop Growth and Physiology Parameters, Yield Parameters, and water productivity had no significant difference under blended fertilizer rate application. But in irrigation intervals, plant height, marketable yield, and total bulb yield of onion were significantly affected. The highest total bulb yield of onion was recorded in the control irrigation (100% MAD) in the interval.
Keywords: Blended fertilizer, Onion, Manageable Allowable Depletion (MAD), Irrigation Scheduling.
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1. INTRODUCTION

The onion (Allium cepa L.) is one of the most vital vegetable crops commercially grown in the world (Grubben and Denton, 2004). Onion has an important economic role in Ethiopia. The country has a massive potential to produce a crop throughout the year both for domestic use and the export market. Its production also contributes to the commercialization of the rural economy and creates many job opportunities (Nikus and Mulugeta, 2010; Guesh, 2015). The onion is valued for its distinctive pungency and forms an essential ingredient for flavoring varieties of dishes; sauces, soups, sandwiches, and snacks such as onion rings.

Onions need various nutrients to sustain their growth and development. Onions require a high level of soil fertility to support high yields. Although the fertilizer requirement depends on the type of crops produced, the fertility status of the soil, and the environmental conditions of the area. Ethiopia has been using the blanket recommendation of 200 kg DAP (ammonium sulfate) and 150 kg urea per hectare, which may not satisfy the nutrient requirements of onion plants. Therefore, the Ministry of Agriculture and Natural Resources (MoANR) has recently introduced a new NPS fertilizer, which contains N, P2O5, and S with a concentration of 19%, 38%, and 7%, respectively. According to MoANR (2013), DAP is substituted with NPS fertilizer. Khokhar et al., 2004; Khalid, 2019 reported that the onion requires an intensive supply of plant-available macronutrients, namely, nitrogen (N), phosphorus (P), and potassium (K) to attain a maximum yield of bulbs, because the plants have a shallow, sparsely branched root system, and NPK fertilizer at a rate of 100:33:62 significantly influenced onion yield. As Khalid (2019) also revealed, the application of micronutrients has a significant improvement in onion yield at a rate of zinc sulfate (ZnSO4 at 0.5%), iron sulfate (FeSO4 at 1.0%), and boron (B at 0.5%). Blended fertilizers containing both macro and micro elements may possess this characteristic. As the Ethiopian Agricultural Transformation Agency reported (2016) N: P2O5:S: B(18.9N-37.7P2O5-6.95S-0.1B), fertilizer will substitute DAP all over part of the onion growing area of Ethiopia. However, the response of onion to the application rate of the newly introduced blended fertilizer (NPSB) under the Debre Zeit area agroecological condition was not yet known. Therefore, the objective of the activity was initiated to determine the optimum rate of balanced fertilizers and irrigation intervals for onion crops and to identify the interactive effect of nutrient and moisture levels on the yield and yield quality of onions.

2. MATERIAL AND METHODS INTRODUCTION

2.1. Description of the Study Area

The experiment was conducted in the 2016-2018 cropping season at Debre Zeit Agricultural Research Center, the main station. The geographical location extent ranges from 08o 44' 15" to 08 o 46' 45" N Northern latitude and from 38o 59' 45' to 39 o 01' 00" E Eastern longitude. The research center is located at the level of a very gently sloping topography with a gradient of zero to 2 %. . It has a low relief difference with an altitude ranging from

1610 to 1908 meters above sea level. The site is situated in the central highland area of the country, having a Tepid to cool sub-moist highland-type climate. The area receives an annual mean rainfall of 851 mm. The mean maximum and minimum temperatures are 28.3 0C and 8.9 0C, respectively, with an average value of 19 0C. The experimental fields are dominated by heavy soils (Vertisol)) (WRB, 2014). The source of irrigation water in the study area is groundwater and soil.

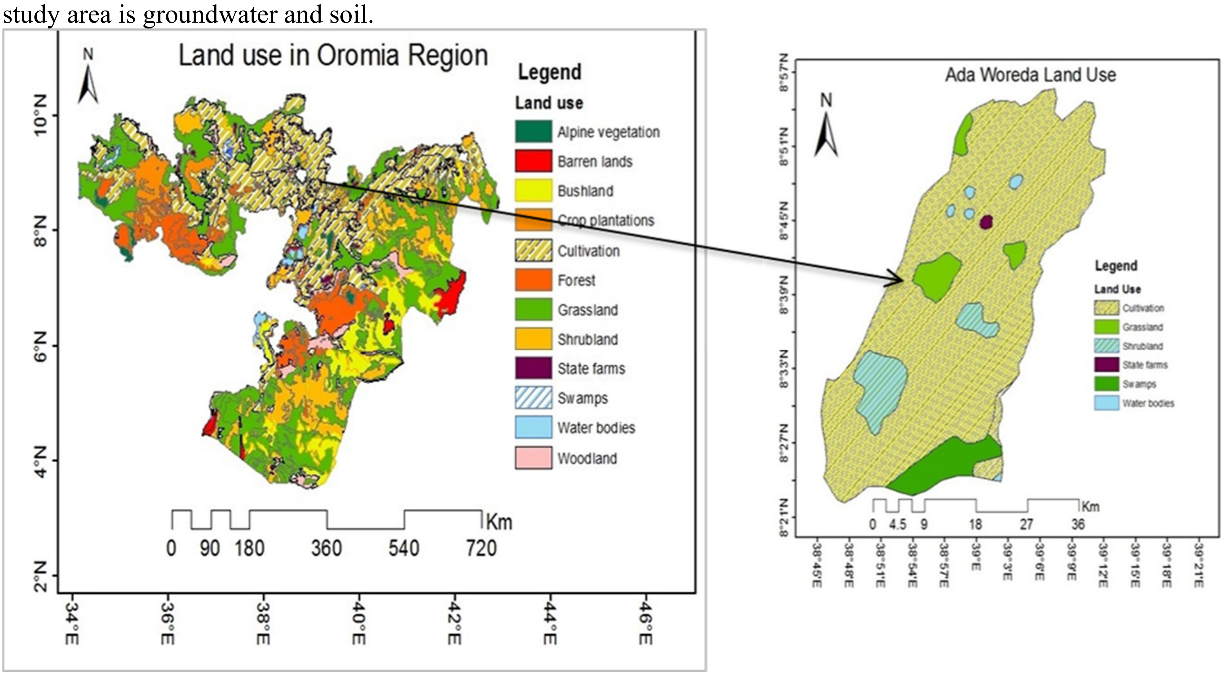

Figure 1 Location map of study area

2.2. Treatments and Experimental Design

The experimental treatments had three irrigation intervals, viz., 80%MAD, 100%MAD, and 120%MAD, and three Fertilizer rates of application, viz., 100kgha^{-1} NPSB, 150kgha^{-1}NPSB and 200kgha^{-1}, and a control fertilizer rate of 100kgha^{-1} urea. The design of the experimental plot was a split plot in RCBD arrangement and replicated three times. The three irrigation intervals were arranged as main plots and the fertilizer rates as subplots. The experiment had a total of twelve (12) treatment combinations. The experimental field was divided into 36 plots 3m by 4m to accommodate six furrows with a spacing of 60cm having row and plant spacing of 20cm and 10 cm, respectively. The plots and replications had a buffer zone of 2m for canals carrying irrigation water and 2.5 m for canals carrying irrigation water supply canals between plots to eliminate the influence of lateral water movement and also 1.5m between plots. The experimental treatment combination and designation are given in Table 1.

Table 1: Treatment combinations

Treatment	Fertilizer rates (subplot)			
Irrigation Intervals	RN P	100 Kg Map Recommended	150 Kg Map Recommended	200 Kg Map Recommended
(main plot)				
80% MAD	T1	T2	T3	T4
100% MAD	T5	T6	T7	T8
120% MAD	T9	T10	T11	T12

Remark:-RNP = Recommended nitrogen and phosphorus

- ✓ Map recommended formula means the balanced fertilizer (Formula) identified from the map generated by ATA for the implementing woreda
- ✓ The amount of N available at formula may not be enough for crop, so the remaining will be added by applying additional N from urea.
- ✓ MAD is manageable allowable depletion level of the test crop from FAO/ EIAR recommendation.

2.3. Crop Management Practices

All agronomic crop management practices are dates of site selection, land preparation, sowing, seedling preparation, transplanting, treatment application, crop management practice, maturity, and harvest. The onion (Allium cepa L.) seed variety Nafis was used as seed material. The selected seed variety was sown on the nursery bed. The seedlings were then transplanted on well-prepared experimental plots and the seedlings were established on both sides of a ridge with row and plant spacing of 20cm and 10cm, respectively.

The depth of irrigation water to be applied in each treatment was based on the allowable soil moisture depletion level and the control plot (100% ETc) should deplete 25% of the total available water in the root zone before the next irrigation. The required depth of irrigation water to be applied in each irrigation application was measured using the Parshall flume.

2.4. Crop water requirement and Irrigation water management

The average ETo value of the experimental site was 4.1 mm/day. Using the reference evapotranspiration (ETo) and crop coefficient value, the calculation of the total seasonal onion crop water requirement was found to be 414.73mm. The Crop water requirement (ETc) values were low at the beginning of the initial growing season, increased gradually to attain a maximum during development and mid-stage and subsequently decreased based on crop growth stages and climate data.

Table 2: The climate data of 42 years (1975-2017) for the study Area

Month	T max (°C)	T min (°C)	Humidity (%)	Wind (m/s)	Sunshine (hrs)	Rad. (MJ/m²/day)	ETo (mm/day)	Rainfall (mm)	Eff. Rainfal (mm)
January	25.2	8.9	63.0	1.3	9.8	22.0	4.0	9.4	0.0
February	26.3	10.2	46.4	1.4	8.5	21.4	4.4	24.8	4.9
March	27.0	11.3	46.4	1.5	8.1	21.8	4.7	31.5	8.9
April	27.1	11.9	47.7	1.5	7.1	20.4	4.6	44.2	16.5
May	27.7	11.6	46.5	1.6	8.6	22.2	4.9	41.3	14.8
June	26.4	11.4	54.9	1.0	6.3	18.4	3.9	88.9	47.1
July	23.7	12.1	66.4	0.9	4.9	16.4	3.3	235.1	164.1
August	23.9	12.1	67.8	0.9	5.5	17.7	3.5	208.2	142.6
September	24.1	11.5	63.3	0.8	6.7	19.6	3.7	83.6	42.9
October	25.0	9.5	49.9	1.4	8.6	21.7	4.3	25.9	5.5
November	24.6	8.0	47.0	1.3	9.3	21.4	4.1	7.4	0.0
December	24.8	7.4	46.9	1.4	9.4	20.9	4.0	1.0	0.0
Total								**810.3**	**447.3**
Average	**25.5**	**10.5**	**53.9**	**1.2**	**7.7**	**20.3**	**4.1**		

3. RESULTS AND DISCUSSION INTRODUCTION

3.1. Soil Sampling and Analysis

The results of soil analyses and field tests on physical and chemical characteristics are given in Tables 3 and 4.

3.1.1. Soil Physical Characteristics

In-depth laboratory analysis indicates that the basic particle size distribution in the soil was an average value of 53.60% clay, 22.53% sand, and 23.87% silt at the experimental site. Therefore, based on the soil textural class determination triangle of the international soil society (ISSS) system (Rowell, 1994) the soil of the experimental site was clay in texture. The bulk density of the experimental site showed slight variation in-depth and varied from 1.04 to 1.15g/cm3. This could be because of a slight decrease in organic matter with depth and compaction due to the weight of the overlying soil layer (Brady and Weil, 2002). The weighted bulk density (BD) and Total Available Water (TAW) of the experimental site are given in Table 3.

Table 3: Soil physical properties

Depth (cm)	**BD (g/cm3)**	**FC (%)**	**PWP (%)**	**TAW (mm)**	**Clay (%)**	**Sand (%)**	**Silt (%)**	**Textural class**
0-20	1.04	39.35	23.76	32.43	53.6	23.2	23.2	Clay
20-40	1.1	41.94	24.58	38.19	55.6	25.2	19.2	Clay
40-60	1.15	39.9	24.94	34.41	51.6	19.2	29.2	Clay
Average	1.01	40.40	24.43	35.01	52.93	22.53	23.87	Clay

Note: FC: Field Capacity
PWP: Permanent Wilting Point

3.1.2. Soil Chemical Characteristics and Water Properties

Soil PH is an important parameter that measures hydrogen ion concentration in the soil to indicate the acidic and alkaline nature of the soil. According to Murphy's (1968) rating scale, the pH value of the current experimental site soils was near to neutral (pH 7.07). Onions can grow well in soil with a pH ranging from 6.0 to 8.0 (Olani and Fikre, 2010). The soil had a cation exchange capacity (12.77meq/100g) through a 60 cm profile and average electrical conductivity of (0.280ds/m), which is below the threshold value for onion yield reduction, i.e. 1.2 dS/m (Smith et al., 2011). Organic matter content (OM) improves water-holding capacity, nutrient release, and soil structure. The OM content and OC content of the soil had average values of 1.80% and 1.05%, respectively, which is rated as low. The findings of Tekalign (1991) reported that soils having OM values in the range of 0.86-2.59%

are considered low.

The laboratory result of the irrigation water showed a pH value of 7.47 and an ECw value of 0.67 dS m -1 (Table 4). According to Bryan et al. (2007), irrigation water is classified in terms of pH as low (below 7), slight to moderate (7-8), and severe (above 8). Based on this classification, the characteristics of the irrigation water in the study area are found slight to moderate (Table 4).

Bauder et al. (2014), reported that irrigation water quality salinity hazard has four categories: (≤ 0.75 dS m^{-1} none), (0.76-1.5 dS $^{m-1}$ some), (1.51-3.00 dS m^{-1} moderate) and (≥3.00 dS m -1severe). Based on the above categories, the irrigation water quality of the study area has been classified as none.

Table 4: Soil chemical and Water properties

Depth(cm)	pH	CEC(meq/100)	EC(ds/m)	OC (%)	OM (%)
0-20	7.10	14.7	0.298	1.15	1.98
20-40	7.11	13.9	0.265	1.12	1.93
40-60	7.00	9.7	0.278	0.87	1.50
Average	7.07	12.77	0.280	1.05	1.80
Irrigation Water					
pH	7.0				
ECw	0.67ds/m				

Note: OC: Organic Carbon

3.2. Crop Growth and Physiology Parameters

3.2.1. Plant height

Recorded analysis of variance has shown no significant difference in plant heights amongst the different fertilizer rate levels. But statically, there is a difference as the table shows the highest plant height of (35.81cm) was recorded from the 100NPSB balanced fertilizer rate and had no significant differences with other balanced fertilizer rates. The irrigation intervals had a significant ($P<0.05$) effect on onion plant height. The irrigation interval of (120% MAD) application gave the highest plant height and was significantly different from all other irrigation intervals. The shortest plant height of (32.98cm) was recorded from the irrigation interval of the (100%MAD) application but did not significantly affect the 80%MAD irrigation interval. The interaction effects of fertilizer rate application and irrigation intervals had no significant effect on the plant height of the onion (Table 5). The tallest plant height of (36.10cm) was recorded from the maximum irrigation interval of (120% MAD) and was significantly different from all irrigation intervals. The shortest plant height of (32.98cm) was recorded from the irrigation interval of (100%MAD) application and was significantly inferior to all irrigation levels affected to the 80%MAD.

This result is similar to the findings of Mebrahtom et. al, 2020, who reported that onion plant height was not a significant difference in blended fertilizer application in irrigation conditions, but there are opposite findings by Morsy et al. (2012) and Nasreen et al. (2007) who reported that onion plant height significantly increased as the rate of blended fertilizer was increased.

3.2.2. Number of leaves per plant

The result of the analysis showed that the number of leaves per plant was not significantly affected by both fertilizer rate and irrigation intervals. The interaction effects of fertilizer rate and irrigation intervals had no significant effect on the number of leaves per plant (Table 5). The maximum number of leaves per plant was recorded from the 200%NPAB fertilizer rate and had no significant difference from others. The irrigation interval of (100% MAD) gave the highest number of leaves per plant and was not significantly different from all irrigation intervals. The lowest number of leaves per plant (11.43) was recorded from 80%MAD irrigation application and statically inferior to all irrigation intervals.

3.2.3. Leaf length

The interaction result of fertilizer rate and irrigation intervals did not affect onion leaf length. The irrigation intervals had no significant effect on onion leaf length. Among the fertilizer rates, it seems there was no significant difference between all rates. And a 100%NPSB fertilizer rate gave statically higher leaf length than all other rates. Among the irrigation intervals, the highest leaf length was recorded by 80%MAD application and was statically different from all other irrigation intervals. The irrigation interval of 120% MAD application, on the other hand, gave the lowest leaf length with a value of (18.10 cm).

Table 5:Response of Fertilizer rates and irrigation intervals on plant height, leaf number & length

Fertilizer Rate ($kgha^{-1}$)	PH (cm)	LN	LL (cm)
100 NPSB	35.81	11.84	19.38
100 UREA	34.65	11.02	17.59
150 NPSB	34.96	12.09	18.78
200 NPSB	34.5	12.42	18.93
LSD(P <0.05)	Ns	Ns	Ns
MAD (%)			
80	33.44b	11.43	19.72
100	32.98b	12.15	18.18
120	36.10a	12.03	18.1
LSD (P<0.05)	3.12	Ns	Ns
CV (%)	16.67	20.8	23.8

3.3. Yield and Yield Parameters

3.3.1. Onion bulb diameter

The onion bulb diameter was measured to grade the size and quality of the onion produced. The analysis of the variance for bulb diameter has shown no significant difference between the fertilizer rate and also irrigation intervals. The interaction of fertilizer rate and irrigation intervals did not affect onion bulb diameter (Table 6). The control fertilizer rate (100% urea) gave the highest onion bulb diameter of (6.68cm) and had no significant difference with others. The smallest bulb size (6.56cm) was recorded from a 150% NPSB blended fertilizer rate application and no significant difference to all other fertilizer rates.

3.3.2. Onion bulb height

Although the analysis of variance has shown that there was no significant difference between the different fertilizer rates and irrigation intervals. The interaction effect of fertilizer rates and irrigation intervals has no significant effect on the bulb height of the onion.

A statically higher bulb height of (5.62cm) was recorded from a 100%NPSB fertilizer rate application and had no significant difference with other fertilizer rate applications. The shortest bulb height (5.48cm) was recorded from the recommended fertilizer rate application and had no significant difference between fertilizer rate applications. Based on irrigation intervals, 120% MAD has recorded higher bulb height of onions but no significant effect on others.

Table 6: Different Fertilizer rates and irrigation intervals on onion bulb diameter and bulb height

Fertilizer Rate ($kgha^{-1}$)	BD (cm)	BH (cm)
100 NPSB	6.66	5.62
100 UREA	6.68	5.48
150 NPSB	6.56	5.57
200 NPSB	6.62	5.51
LSD (P <0.05)	Ns	Ns
MAD (%)		
80	6.34	5.43
100	6.78	5.6
120	6.76	5.62
LSD (P <0.05)	Ns	Ns
CV (%)	11.62	10.01

3.3.3. Marketable Bulb Yield

Analysis of variance has shown that the marketable bulb yield of onion was not significantly affected by fertilizer rates but in Irrigation intervals there is significance difference. Similarly, the interaction effect of fertilizer rates and irrigation level has not significantly affected the marketable bulb yield of onions. The 200%NPSB fertilizer rate with irrigation intervals scheduled at the control (100%MAD) application gave statically the highest marketable bulb yield of (40698 kg ha-1). Among the irrigation intervals, the control irrigation interval (100%MAD) practices have shown a significant difference in marketable bulb yield, which is 38506 kg ha-1. The irrigation interval application of 80%MAD gave significantly the lowest marketable bulb yield of (33581 kg ha-

1). Generally, among the fertilizer rate, 100%urea produced the best marketable bulb yield (38214kgha^{-1}), while the significantly lowest mean marketable bulb yield (35642kgha^{-1}) was obtained from 200%NPSB fertilizer rate application.

AS Mebrahtom et, al (2020) reported that in the application of blended fertilizer rate at irrigation conditions there is no onion yield response. Statically, the higher fertilizer rates the yield too. But Awoke et.al (2021) reported that the application of blended fertilizer increased the yield of hot pepper.

3.3.4. Unmarketable bulb yield

No significant analysis of variance has shown that unmarketable bulb yield was not significantly affected by the interaction effect of fertilizer rates and irrigation intervals. Fertilizer rates and irrigation intervals have also shown don't have a significant difference in unmarketable bulb yield (Table 7).

The fertilizer rate of 200%NPSB gave the lowest unmarketable bulb yield (512.82kgha^{-1}) and has no significant difference with other fertilizer rates. The irrigation interval of 120%MAD gave the lowest unmarketable bulb yield.

3.3.5. Total bulb yield

The total bulb yield was the sum of unmarketable and marketable bulb yield of onions. Total bulb yield was not significantly affected by the interaction effect of fertilizer rate and the irrigation interval and whilst, in the irrigation interval there was a significant difference in total bulb yield in the fertilizer rate, there was no significant difference.

Significantly, the control irrigation interval (100% MAD) gave the maximum total bulb yield of (38922kg ha-1) and had a significant difference between 80% MAD and 120%MAD practice. In fertilizer rate, significantly the highest yield was obtained from 100UREA which is (38655kgha^{-1}) and the lowest total bulb yield was obtained from 200NPSB fertilizer rate. Significantly, the lowest total bulb yields (34060kgha^{-1}) were obtained from the 80%MAD practice. Generally, the result showed that in irrigation intervals there is significant difference between the control and the other treatments. But, the fertilizer rate had no significance difference results. Similarly, Mebrahtom et al (2020) also reported that the application of blended fertilizer in irrigated conditions was no significant difference, but the statically significant difference as fertilizer rate increased yield also increased.

3.3.6. Water Productivity

On the crop production system, water productivity (WP) is used to define the relationship between crop production and the amount of water involved in crop production, expressed as crop production per unit volume of water. The analysis of results showed that both the fertilizer rate and the irrigation interval are not significantly different, the same as the interaction result., statically the highest water productivity was recorded in the fertilizer rate of 100urea, and in the irrigation interval, 80% MAD was recorded as the highest water productivity 100 as the highest.

Table 7: Responses of different Fertilizer rates and irrigation intervals on Marketable yield, Unmarketable yield, Total bulb Yield, and Water Productivity of Onion

Fertilizer Rate (kgha^{-1})	MAY (kgha^{-1})	UNY (kgha^{-1})	TBY (kgha^{-1})	WP (m^{3}kg^{-1})
100 NPSB	35663	548.47	36151	3.37
100 UREA	38214	540.89	38655	3.39
150 NPSB	36878	608.45	37459	3.57
200 NPSB	35642	512.82	35869	3.32
LSD(P <0.05)	Ns	Ns	Ns	Ns
MAD (%)				
80	33581^{b}	548.04	34060^{b}	2.9
100	38506^{a}	595.38	38922^{a}	3.63
120	37712^{ab}	514.56	38118^{ab}	3.74
LSD (P <0.05)	3229.7	Ns	5137.1	Ns
CV (%)	21.41	26.93	21.20	28.28

- ✓ ü Di-ammonium phosphate **(DAP**) _(NH4)2HPO4
- ✓ Ø Phosphorus (P2O5) = 46% &
- ✓ Ø Nitrogen (N) = 18%
- ✓ ü Urea CO(NH2)2
- ✓ Ø Nitrogen(N) = 46%
- ✓ ü Triple super phosphate(TSP)_3Ca(H2 PO4)2
- ✓ Ø Phosphorus (P2O5) = 46%

Recommendation of **Urea** for onion 100kgha-1
Recommendation of **DAP** for onion 200kgha-1or **NPS** = 242kgha-1
0.1 Boron

NPSB
19% Nitrogen
16.4% Phosphors
6.95% Sulfur
0.1 Boron

NPSBZn
18% Nitrogen
15.6%Phosphorus
7.7% Sulfur
2.2% Zink

CONCLUSION

Based on the three-year experiment finding application of different rates of blended fertilizer on onion crops in the vertisol area under irrigation conditions does not significantly affect most of the onion crop parameters such as plant height, leaf length, number of leaf bulb diameter, bulb height, and bulb yield. The maximum total bulb yield of (43155kg ha-1) was recorded at 100% Urea fertilizer application. Therefore, it can be concluded that even though blended fertilizer does not have a significant difference among the treatments in all agronomic attributes, Urea fertilizer was recorded as the best bulb yield of onions. Under irrigation conditions, the control irrigation (100%) application gave the highest bulb yield of onions.

Therefore, based on the results of the study, using blanket recommendations for blended fertilizer all over the area and soil type may not be correct. It can be recommended that further study should be conducted on soil test-based application of blended fertilizer and on-site specific conditions, because the availability of the element may vary depending on the nature of the soil type and climate condition.

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