Hindawi
International Journal of Agronomy
Volume 2019, Article ID 8125063, 10 pages
https://doi.org/10.1155/2019/8125063

Research Article

Optimizing Irrigation Water and N Levels for Higher Yield and Reduced Blossom End Rot Incidence on Tomato

Mebrahtu Gebremariam [1] and Teklay Tesfay [2]

[1] *Department of Plant Sciences (Horticulture Program), Aksum University Shire Campus, P O Box 314, Shire, Ethiopia*
[2] *Department of Plant Sciences, Aksum University Shire Campus, P O Box 314, Shire, Ethiopia*

Correspondence should be addressed to Mebrahtu Gebremariam; mebre2003hu@gmail.com

Received 13 September 2019; Revised 16 November 2019; Accepted 26 November 2019; Published 27 December 2019

Academic Editor: Allen Barker

This study was conducted during 2018/19 under drip irrigation in the dry season to examine the effect of irrigation and N levels on yield, economic performance, and incidence of blossom end rot (BER) on tomato. A 3×4 factorial design with subdivided plots was implemented. Three irrigation levels (50%, 75%, and 100% ETc) were randomly assigned in the main plots and four N levels (0, 46, 92, and 138 kg ha^{-1}) to the subplots. Climate data were imported into AquaCrop model climate dataset for determining irrigation water amount and irrigation scheduling. Irrigation scheduling was determined using the FAO AquaCrop model. Data were subjected to analysis of variance (ANOVA) using GenStat software. There was significant interaction effect of irrigation and N levels on yield, yield parameters, and BER incidence on tomato. Highest fruit diameter and fruit length were attained from the combined application of 75% ETc and 138 kg N ha^{-1}. Besides, maximum fruits per plant and marketable yield were obtained under combined use of 100% ETc with 138 kg N ha^{-1} and 75% ETc with 92 kg N ha^{-1}, respectively, whereas lowest yield performance was recorded when 50% ETc is coupled with 0 kg N ha^{-1}. However, highest (21.91%) and lowest (7.03%) BER incidence was found under the combined use of 50% ETc and 0 kg N ha^{-1} 100% ETc and 92 kg N ha^{-1}, respectively. The economic analysis revealed that application of 46 kg N ha^{-1} was economically feasible irrespective of the irrigation water levels.

1. Introduction

Several studies have indicated that plant yield can be increased by increasing nutrient application rates [1, 2]. However, nutrient supply may be affected by the level of irrigation water applied. Deficit irrigation can help to reduce production costs, conserve water, and minimize leaching of nutrients and pesticides into ground water [3]. Moreover, water deficiency results in high fertilizer expenses [4–6] and reduced plant growth performance [7–12]. Conversely, the excessive application of irrigation water level has become a serious concern for sustainable crop production [7]. Many studies have reported on significant interaction effect of irrigation water and N application levels on crop yield [13–21]. Specifically, studies conducted on tomato indicated that the interaction between N supply and irrigation management affects yield [22–25], more important than the influence of individual factor. Indeed, crop qualities are very sensitive to appropriate water and nutrient contents in the root zone of plants [23]. This validates that both excessive and insufficient irrigation and nutrient application rates have substantial effects on crop yield. Farmers rely on the traditional practices for supplying water and N, which prevents the effective use of water and fertilizer [22]. Therefore, optimizing the N application doses with different irrigation water levels are crucial for a higher tomato fruit yield and better quality.

Tomato (*Solanum lycopersicon* L.) is one of the most important vegetables all over the world and mostly grown under irrigation for their edible fruits and nutritional values [26, 27]. However, in Ethiopia including the study area, its productivity is very low (10 t ha^{-1}) [28] as compared to the world average yield of 17.27 t ha^{-1} [29]. Some of the reasons for the low productivity of tomato include inadequate irrigation and fertilizer application, use of low yielding varieties, incidence of BER, pests, and disease incidence. Among these factors, inadequate supply of irrigation level [25] and N rates [30] are particularly crucial for contributing to lower yield and increased risk of BER incidence on tomato [22]. Although tomato responds well to nitrogen fertilizer application rates under different irrigation levels, the blanket recommendation of N fertilizer application is common in agricultural production [31]. Based on the OARD [28] report, the smallholder farmers of the study area apply mineral N rate at a range of 0–69 kg ha^{-1} under variable irrigation application levels for tomato production. On the other hand, more than 69% of tomato producers in the study area are suffering from reduced yield due to the incidence of blossom end rot (BER) [28].

BER is a physiological disorder common in all the tomato producing areas of the world and has been revealed to cause yield losses up to 50% [32–34]. This disorder can happen due to many factors like slow transportation of Ca to the plant, poor uptake of Ca through the stem, lack of Ca in the soil, and/or too much N in the soil [35]. A high level of available N, which promotes vigorous plant growth and fruit development, has been shown to raise susceptibility to BER [36]. However, since plant Ca moves with the transpiration stream through the xylem to growing fruit, soil water content is very important for Ca uptake. It has also been reported that the occurrence of BER was lower with a higher quantity of irrigation in tomato [37].

Moreover, various earlier research findings have signified that BER is not induced by one particular factor, but by an integration of one or more factors intensifying the effect, such as high Na, Mg, NH_4, and K quantity [1], which may cause antagonistic effect against Ca uptake, vigorous growth rate [38], low soluble soil Ca [39], and high [40] and low transpiration [39]. An experiment conducted by Franco et al. [37] indicated that water stress (27 days after planting, irrigation reduced by one-half until the end of the season) significantly increased the incidence of BER in drip irrigated tomatoes. Meanwhile, Paiva et al. [41] reported a substantial reduction in the incidence of BER in response to irrigation during a dry year.

Application of irrigation water and N management strategies to tomato may significantly lead to save irrigation water [42], decrease incidence of BER [37], and enhance fruit yield [22, 24, 43]. However, in the study area, tomato production is suffering from low productivity and frequent occurrence of BER. Moreover, little information is available on the best integrated use of irrigation water level and N fertilizer rates needed to reduce incidence of BER and achieve higher yield of tomatoes [28]. Consequently, it is of great interest to growers to adopt practices that optimize irrigation water and N levels that reduced BER incidence and enhance fruit yield of tomato.

Therefore, optimizing irrigation water and nitrogen application levels and adopting their best integrated use as a management tool for tomatoes production could be very important in situations where water is scarce, mineral fertilizer is costly, and BER incidence is high. However, before adopting their integrated use as a best practice, determining their interaction effect on tomato yield [44, 45], economic values, and incidence of BER [31] could be crucial. Thus, this research was, therefore, designed to optimize irrigation water and N levels for higher yield, better economic performance, and reduced BER incidence on tomato under the study area.

2. Methodology

2.1. Description of the Study Area. This research was carried out in the Aksum University Selekleka Research and Technology Transfer Center during 2018/19 under drip irrigation in the dry season. According to the climatic zone classifications of Ethiopia [46] which was based on altitude, rainfall, average annual temperature, and length of growing season, the study area belongs to cool subhumid agroclimatic zone. The experimental area is situated at 14° 08′ 57″N latitude and 38° 17′ 02″E longitudes at an altitude of 1945 m.a.s.l. The main rainy season of study area extends from June to September with the mean annual rainfall of 980.36 mm. Rainfall distribution of the study area is characterized by a unimodal pattern where more than 90% of it is concentrated in the period between July and August. The average temperature of the study area for the past 15 years revealed 20.92°C with a mean maximum temperature record (28.64°C) in April and the mean minimum (10.9°C) in January [47].

According to the FAO/UNESCO [48] soil map, the soil type of the study area is vertisol with relatively neutral soil pH (7.5) and a low EC (0.864) level. Generally, soil of the study area had low organic matter content (0.873%), total N (0.086%), available P (6.613 ppm), available K (40.1 ppm), and exchangeable Ca (4.4 cmol (+) kg^{-1}). The low fertility level of the study area might be possibly due to continuous cultivation of cereal crops.

2.2. Experimental Design and Treatments. The experiment was laid out in a 3×4 factorial design with subdivided plots. Treatment combination of three irrigation levels (50%, 75%, and 100% ETc) and four N rates (0, 46, 92, and 138 kg N ha^{-1}) with three replications was used. There were a total of 12 treatment combinations and three replicates of each treatment combination. Irrigation levels were randomly assigned to the main plots, whereas the four urea sourced N levels (0, 46, 92, and 138 kg N ha^{-1}) were randomly arranged in the subplots. Size of individual plot was 3 m by 4 m with 1 m and 1.5 m space between plots and blocks, respectively. Tomato (cultivar Galilya) seedlings were raised in a nursery using seedling trays and transplanted to the experimental field after they produced 6–8 leaves. The land was ploughed twice using a tractor and prepared for planting using manpower. The spacing between plants and rows were 40 cm and 100 cm, respectively. Watering was applied through drip irrigation pumped from a well. The treatments were applied to tomato plants just after seedlings have been established in the experimental plots. All the agronomic activities including weeding, fertilizing (TSP application), cultivation, staking, and disease and insect pest control were carried out for all the experimental plots equally as per the recommendations. Mineral N fertilizer was applied in three splits (one-third was applied just after tomato seedlings being established, the other two-third during the vegetative growth period). Urea was employed using drilling on the sunken circle around each plant and then buried with soil.

2.3. Computation of Crop-Water Requirement and Irrigation Scheduling. Climate data were imported into the AquaCrop model climate dataset for determining irrigation water and irrigation scheduling. Irrigation scheduling was determined using the FAO AquaCrop model [49, 50]. The crop water requirement (ETc) in the AquaCrop model was determined using the Penman–Monteith method following the procedures in Allen et al. [51]. Irrigation was set until the soil reaches field capacity (*back to field capacity*). This was estimated by the amount and discharge rate of water from every emitter of the surface drip irrigation to each tomato plant which was measured and calibrated by taking three dripper points (at the initial, middle, and end) of each lateral using a graduated beaker and stop watch. The amount of water applied to refill the required depleted moisture was given to the crop during the time of irrigation. Therefore, based on the model output, amount of irrigation water (mm) for 100%, 75%, and 50% ETc was 581.3, 435.97, and 290.65 mm, respectively. Appropriate irrigation schedules can reduce N loss, enhance crop growth, and increase yields [20, 52], and hence it was determined using soil water balance method computed following the procedures in FAO-56 Irrigation and Drainage paper [51]:

$$\mathrm{ETc} = \mathrm{P} + \mathrm{I} - \mathrm{RO} + \mathrm{D} + \mathrm{C} \pm \Delta \mathrm{S}, \quad (1)$$

where ETc is crop evapotranspiration, P represents for precipitation, I is total irrigation water amount applied to experimental plots from the time of transplanting to last harvest, RO stands for runoff, D is water loss by deep percolation, C is capillary rise, and ΔSrepresents change in soil moisture content determined as the difference between total moisture during transplanting and after the last harvest. All terms are expressed in mm of water. P and RO are assumed to be zero since there was no rainfall during the experiment and the amount of irrigation water was controlled. Indeed, D was considered to be zero because the irrigation water was sufficient to reach the field capacity and C is negligible in the semiarid study area. Therefore, the water balance formula could be simplified to

$$\mathrm{ETc} = \mathrm{I} \pm \Delta \mathrm{S}. \quad (2)$$

Irrigation treatments were applied after tomato seedlings were well established and irrigation water was applied when 40% of the readily available water (RAW) was depleted from the root zone. Irrigation water required for the treatments was applied early in the morning and late in the afternoon using drip irrigation.

2.4. Data Collection and Analysis

2.4.1. Soil Sampling and Analysis. A representative soil sample was taken from the experimental field before transplanting. A composite of disturbed soil sample was taken using Augur (a sample was collected, dried, composited, and sieved using 2 mm sieve to prepare a 1 kg composite sample) for the determination of selected soil physical and chemical properties which include soil texture, organic matter, pH, EC, total N, exchangeable Ca, available P, and available K. Texture (particle size distribution) was determined using the Bouyoucos hydrometer method [53]; soil pH in a suspension of 1 : 2.5 soil-water ratio was determined by using a pH meter [54, 55]; total N determination was done by the macro Kjeldahl method [55]; and available P was determined using the Olsen method [56]. Organic matter content of the soil was estimated from the organic carbon content determined using the Walkley and Black [57] method.

2.4.2. Agronomic Data Collection. Fruit diameter, fruit length, number of fruits per plant, marketable fruit yield (Y_{m}), and incidence of BER were measured at each harvest time, and values for parameters like number of fruits per plant and marketable fruit yield (Y_{m}) were summed up at the end of the experiment, while the values of fruit diameter, fruit length, and incidence of BER in each harvest were summed up and the average value was considered. For all parameters, the tomato plants in the middle rows were considered for data collection. To collect data on fruit diameter and fruit length, five randomly collected fruits were considered while the length and diameter of each fruit were measured using a digital caliper, and the average value was computed for each plot. BER incidence was calculated by dividing the number of fruits with BER symptom (fruits having black tissue at the base) to the total number of fruits and multiplied by 100% during the harvest time.

2.4.3. Statistical Analysis. The collected data from every plot were initially checked for their normality, and they were subjected to analysis of variance (ANOVA) procedures suitable for an experiment in a factorial design using GenStat Version 16 statistical software. Mean separation was done by LSD (least significant difference) at 5% probability level to determine the effects of irrigation and N fertilizer levels on yield and yield attributing characters of tomato. Moreover, regression analysis was performed to see the relationship among the independent (irrigation and N application levels) and response variables (marketable yield and BER incidence).

2.4.4. Economic Analysis. The economic analysis for every treatment was carried out using the partial budget analysis based on the CIMMYT [58] approach which utilizes partial budgeting combined with marginal analysis. Partial budget analysis was carried out to determine the most economically acceptable treatment by estimating the varying costs and benefits based on the current market prices.

The varying fertilizer and labor costs were estimated based on the existing rate of fertilizer purchase and daily labor payment. Farm gate price of tomato yield harvested was calculated based on the existing market price. Marginal analysis was carried out using the following procedure:

(1) Dominance analysis (identification and elimination of inferior treatments): dominance analysis was carried out by first listing the treatments in order of increasing costs that vary. Thus, any treatment that has net field benefits less than or equal to those of a treatment with lower costs that vary is inferior/dominated and was excluded from the analysis.

(2) Calculating marginal rates of return: the change in net field benefits divided by the changes in costs that vary for nondominated treatments is expressed as a percentage.

(3) Comparing the marginal rates of return with the farmers' minimum acceptable rate to find the economically preferable treatment for the trial.

In this study, marginal rate of return (MRR) analysis was carried out on both dominated and undominated treatments in a stepwise manner starting from control to the other treatments. Dominated treatments are those treatments having net income/return that are less than those of treatments with lower costs that vary. CIMMYT [58] and Asumadu et al. [59] provided the minimum rate of return that ranges between 40% and 100%, whereas Farquharson [60] and Shah et al. [61] suggested minimum rate of return to be 100%, especially for poor farmers in developing countries or for technologies requiring substantial changes to a farming system. Accordingly, in this study, 100% minimum acceptable, marginal rate of return was considered for farmers to adopt a new technology.

3. Results and Discussion

3.1. Tomato Fruit Diameter, Fruit Length, and Number of Fruits per Plant. The irrigation water and N application levels strongly affected fruit diameter, fruit length, and number of fruits per plant (Table 1). The greatest fruit diameter (56.10 mm) was observed at irrigation level of 75% ETc combined with 138 kg N ha^{-1} which was not significantly different from the value of fruit diameter obtained under 100% ETc interacted with 138 kg N ha^{-1}. High amount of irrigation water and N application enhances vegetative growth of plant which results in shorter duration for fruit set and growth; hence, lower sized fruits might be resulted. Conversely, the lowest fruit diameter (44.43 mm) was recorded. Conversely, the lowest fruit diameter (44.43 mm) was recorded when the irrigation level of 50% ETc is coming together with the N fertilizer rate of kg ha^{-1}. Fruit diameter was increased by 26.27% under irrigation level of 75% ETc combined with N fertilizer rate of 138 kg ha^{-1} compared to that achieved from the irrigation level of 50% ETc interacted with 0 kg N ha^{-1}. This finding implies that increasing N level to the suitable amount under adequate water supply enhances fruit diameter of tomato. Optimum supply of N and water is required for proper growth and development of tomatoes. Kirnak et al. [62] found that the interactions between irrigation and N levels were highly differed for fruit diameter in muskmelon. Fruit diameter was the highest in the well watered treatment combined with 120 kg N ha^{-1}, where it was significantly enhanced by increased N application rates, whereas the lowest fruit diameter was recorded as severely water stressed (50% ETc) integrated with 120 kg N ha^{-1}. Similar findings have been found by Bhella [63] in muskmelon and Srinivas et al. [64] in watermelon, who showed that water stress decreased fruit diameter.

The highest fruit length (71.60 mm) was attained when an irrigation level of 75% ETc is integrated with N fertilizer rate of 138 kg ha^{-1} which was not significantly different from the fruit length recorded under 50 and 100% ETc interacted with 138 kg N ha^{-1}. On the contrary, the lowest fruit length (60.27 mm) was recorded when 50% ETc irrigation level is interacted with N fertilizer rate of 0 kg ha^{-1}. This result was not significantly varied from value of fruit length obtained from 100% ETc integrated with 0 kg ha^{-1}. Fruit length was reduced by 15.820% when 50% ETc is interacted with 0 kg N ha^{-1} compared to the fruit length obtained from 75% ETc combined with 138 kg N ha^{-1}. Limited supply of N rate under moderate soil moisture stress results in reduced growth performance of tomatoes (such as lower fruit length). This result showed that fruit length was more influenced by N rates than irrigation level. N and water application rates are key factors limiting crop yield and yield components [19]. Similarly, Kirnak et al. [62] reported that the interactions between irrigation and N rates were highly varied in fruit length on muskmelon. Fruit length was found to be highest in the well watered treatment (100% ETc) combined with 120 kg N ha^{-1}, where it was significantly enhanced by increased N application rates, whereas the lowest fruit length was recorded as severely water stressed (50% ETc) was integrated with 120 kg N ha^{-1}. Analogous results have also been presented by Bhella [63] in muskmelon as well as Srinivas et al. [64] in watermelon, in which they indicated that water stress diminished fruit length.

The largest number of fruits per plant (26.27) was achieved whilst 100% ETc is combined with 138 kg N ha^{-1}. Such result did not significantly differ from the treatment with 138 kg N ha^{-1} integrated to 50 and 75% ETc. However, the smallest number of fruit per plant (14.47) was acquired when 50% ETc is coming together with 0 kg N ha^{-1} that was not significantly different with number of fruits obtained from 0 kg ha^{-1} interacted with 75 and 100% ETc. Fruit number was enhanced by 81.55% under combined application of 100% ETc and 138 kg N ha^{-1} compared to the fruit number achieved in 50% ETc coupled with 0 kg N ha^{-1}. This result signified that the increased application of irrigation and N fertilizer levels increased the fruit number of tomato to the highest value. Adequate supply of N under sufficiently moist soil enhances the growth of plants. Likewise, Djidonou et al. [24] reported that number of fruits per plant was significantly affected by the interaction between the irrigation regime and N rates. Under the 50% irrigation regime, fruit number was the lowest at 56 kg N ha^{-1} and was significantly increased at 112 kg N ha^{-1}, whereas increasing N rate beyond 112 kg ha^{-1} did not significantly increase the number of fruit plant at 224 and 336 kg N ha^{-1}.

Table 1: Tomato fruit diameter, fruit length, and number of fruits per plant as affected by irrigation and N application levels.

Treatment combinations		Fruit diameter (mm)	Fruit length (mm)	Total no. of fruits plant^{-1}
50% ETc	0 kg N ha^{-1}	44.43	60.27	14.47
	46 kg N ha^{-1}	48.27	65.65	18.03
	92 kg N ha^{-1}	48.43	65.77	17.73
	138 kg N ha^{-1}	52.05	69.65	22.80
75% ETc	0 kg N ha^{-1}	48.93	64.37	15.20
	46 kg N ha^{-1}	53.37	68.77	18.60
	92 kg N ha^{-1}	51.68	65.80	19.93
	138 kg N ha^{-1}	56.10	71.60	22.73
100% ETc	0 kg N ha^{-1}	47.25	62.40	15.13
	46 kg N ha^{-1}	50.97	66.07	18.27
	92 kg N ha^{-1}	50.82	65.95	18.60
	138 kg N ha^{-1}	53.98	70.08	26.27
LSD		1.24	3.35	2.19
CV (%)		7.20	7.44	3.54

ETc = crop evapotranspiration; LSD = least significant difference at 5% level of probability; CV = coefficient of variation.

Furthermore, Candido et al. [65] reported that pepper plants subjected to periods of water shortage exhibited a significant reduction in the number of fruit plants in peppers with those regularly watered plants, yet only when N fertilizer was applied; this reduction tended to increase with the increasing N dose. This verifies that in water and N scarce conditions, smaller number of fruits may attribute to lower tomato fruit yield [66, 67].

3.2. Marketable Yield and Incidence of BER. The incidence of BER (%) was markedly influenced by the interaction of N and irrigation water levels (Table 2). The highest incidence of BER (21.91%) was recorded from 50% ETc combined with 0 kg N ha^{-1} (where there was nonsignificant variation among all irrigation levels combined with 0 kg N ha^{-1}), whereas the lowest incidence of BER (7.03%) was obtained while 100% ETc is integrated with 92 kg N ha^{-1}. This result was not significantly varied with the incidence of BER recorded from 75% ETc integrated with 92 kg N ha^{-1}. Incidence of BER showed to be triggered (reduced) at varied N levels in which incidence of BER had a decreasing trend from 21.91 to 7.03% as N fertilizer rates go up progressively from 0 to 92 kg ha^{-1}, whereas incidence of BER indicated an increasing pattern from 7.03 to 18.66% as N fertilizer rate increased from 92 to 138 kg ha^{-1} under all irrigation levels. Incidence of BER seemed to be more influenced by N rates (especially under lower and higher rates) compared to the irrigation levels. This indicates that improper N fertilization rates aggravate the incidence of BER development. Similar result was reported by Birhanu and Tilahun [68]. In conformity to this result, Warner et al. [30] reported that blossom end rot was common in drier years in an experiment conducted for four years using five N rates and four cultivars of tomato. High rates of N fertilizer application might inhibit Ca^{2+}, Mg^{2+}, and K^{+} absorption in plants [69] which could be one of the causes for increased incidence of BER. Correspondingly, O'Sullivan [70] reported that irrigation and N levels had a significant interaction result in which the incidence of BER was reduced by irrigation but increased with increasing rates of N on pepper.

In the present study, interactions of irrigation and N application levels markedly affected the marketable yield of tomato. The highest marketable yield (20.50 t ha^{-1}) was recorded from the application of 92 kg N ha^{-1} with 75% ETc that did not significantly vary from the yield obtained under 92 kg N ha^{-1} interacted with 100% ETc. This may be resulted from the presence of favorable soil moisture and sufficient N nutrition during the growing period. Yet, the lowest marketable yield (8.44 t ha^{-1}) was obtained from the application of 50% ETc integrated with 0 kg N ha^{-1}. This finding revealed that marketable fruit yield reduced by 58.83% in the 50% ETc interacted with 0 kg N ha^{-1} compared with 75% ETc coupled with 92 kg N ha^{-1}. In conformity to this result, Du et al. [22] and Li et al. [43] reported that an optimum irrigation and N level combination (75% ETc coupled with 250 kg N ha^{-1}) was required for highest tomato yield. Tomato yield tended to increase with increasing N rates for a given amount of irrigation water. On the contrary, May and Gonzales [71] and Akemo et al. [25] obtained lower tomato yields as soil moisture level was reduced. This result is consistent with various findings reported by Xiukang et al. [66], Xiukang and Yingying [42], Ozbahce and Tari [72], and Du et al. [22].

Reduced marketable yields were recorded from tomato plants produced in the 50% ETc combined with 0, 46, and 138 kg N ha^{-1} while 100% ETc is integrated with 0 kg N ha^{-1} which was mainly caused by the higher incidence of BER and reduced fruit size (fruit diameter and length) under such treatment combinations. Therefore, it is valid to conclude that excessive N application no longer contributed to yield increase under water scarcity. Though the number of fruits per pant was higher in plots treated with 100% ETc coupled with 138 kg N ha^{-1}, the higher incidence percentage of BER contributed to reduce marketable fruit yield of tomato. Therefore, both the lesser and excessive irrigation as well as N application levels could result in decreased marketable fruit yield. Research output by Djidonou et al. [24] showed that lower marketable yield of tomato was recorded from the 50% irrigation level combined with the application of 56 kg N ha^{-1}. In harmony to this result, Du et al. [22] confirmed that marketable fruit yield increased with an increase in

Table 2: Marketable yield and incidence of BER as affected by irrigation and N application levels.

Treatment combinations		Incidence of BER (%)	Marketable yield (t ha^{-1})
50% ETc	0 kg N ha^{-1}	21.91	8.44
	46 kg N ha^{-1}	17.67	11.14
	92 kg N ha^{-1}	7.79	14.79
	138 kg N ha^{-1}	18.66	11.61
75% ETc	0 kg N ha^{-1}	21.50	13.17
	46 kg N ha^{-1}	14.72	15.81
	92 kg N ha^{-1}	7.14	20.50
	138 kg N ha^{-1}	17.12	16.36
100% ETc	0 kg N ha^{-1}	20.21	9.28
	46 kg N ha^{-1}	16.94	12.53
	92 kg N ha^{-1}	7.03	17.67
	138 kg N ha^{-1}	17.35	14.17
LSD		1.24	3.35
CV (%)		7.20	8.27

ETc = crop evapotranspiration; BER = blossom end rot; LSD = least significant difference at 5% level of probability; CV = coefficient of variation.

amount of irrigation (averaging across the N rate) or an increasing N rate (averaging across the irrigation treatments) in tomato (Table 2).

The regression analysis showed nonlinear relationships between irrigation water level and marketable tomato yield as well as BER incidence (Figure 1). Similarly, nonlinear relationship was also obtained among N application levels and marketable tomato yield and BER incidence (Figure 2). Marketable yield of tomato increases with an increase in the application rate of N from 0 to 92 kg ha^{-1} while it starts to decline after it reaches 92 kg ha^{-1}. Though there was nonsignificant relationship, application of N levels ($R^2 = 0.449$) contributed more for the change in marketable tomato fruit yield than the irrigation level ($R^2 = 0.146$). On the other hand, in the reduction of BER incidence, contribution of irrigation water level ($R^2 = 0.581$) was relatively higher than that of N application level ($R^2 = 0.183$). Results of the current experiment suggest that in all irrigation levels, there was an increasing trend in marketable yield of tomato as N rate increases from 0 to 92 kg ha^{-1}, whereas a decreasing pattern of the marketable yield was observed with an increasing N rate beyond 92 kg ha^{-1} (Table 2 and Figure 2). The decrease in marketable yield may be attributed to the smaller number of fruits per plant, reduced fruit length and diameter, and higher incidence of BER.

Application of 138 kg N ha^{-1} led to yield reduction by 3.18, 4.14, and 3.5 t ha^{-1} under 50%, 75%, and 100% ETc irrigation levels, respectively, as compared to the application of 92 kg N ha^{-1} in all irrigation levels (Table 2). Comparable results were also recorded by Djidonou et al. [24] in which better yield was obtained at 112 kg N ha^{-1} while above this rate, fruit yield did not show a significant variation. The research finding of Warner et al. [30], which was a four-year trial, showed that with ample water, crop response to fertilizer N rates was enhanced. In such an experiment, during the dry growing season, maximum marketable yield was obtained with a fertilizer level of 150 kg ha^{-1} and was reduced by a further increase in N rates. The dry situations may have restricted additional development of the crop in response to higher N rates, and further increase in N fertilizer level may have aggravated the moisture stress.

Moreover, May and Gonzales [71] reported that lower yields of tomato were observed as soil moisture levels were decreased. Akemo et al. [25] also found lower yields in dry years as compared to a year with more rainfall. In line with the result of this trial, Djidonou et al. [24] reported that the effects of N rates on the marketable yield of tomato was reliant on irrigation regime as revealed by the significant interaction of irrigation regime by N rate. In agreement with the finding of the present research, several studies on muskmelon [62, 63], on watermelon [64], and on bell pepper [65] have revealed significant interactions among irrigation and N levels for marketable yield.

3.3. Economic Performance Evaluation. Partial budget analysis was used to evaluate the economic performance of each treatment combination. According to the result displayed in Table 3, the maximum net income was recorded when tomato was cultivated under 75% ETc combined with 92 kg N ha^{-1} application levels. Tomato production under lower irrigation level (50% ETc) combined with no N fertilizer application resulted the lowest net income. With an increase in irrigation water level from 50 ETc to 75% ETc and N application rate from 0 kg N ha^{-1} to 92 kg N ha^{-1}, net income was consistently enhanced. Similar results were also reported by Sezen et al. [73] on pepper. This implies that application of irrigation water and N fertilizer beyond 75% ETc and 92 kg ha^{-1}, respectively, seemed uneconomical. Therefore, in the present study, where access to irrigation water is scarce and mineral N fertilizer is costly, better tomato yield could be achieved using moderate irrigation level (75% ETc) integrated with N fertilizer rate of 92 kg ha^{-1}.

Considering marginal rate of return (MRR), though the highest value (64.52%) was obtained when the tomato was cultivated under full irrigation combined with the application of 92 kg N ha^{-1}, smallholder farmers prefer low cost of production with high income, and thus it is necessary to

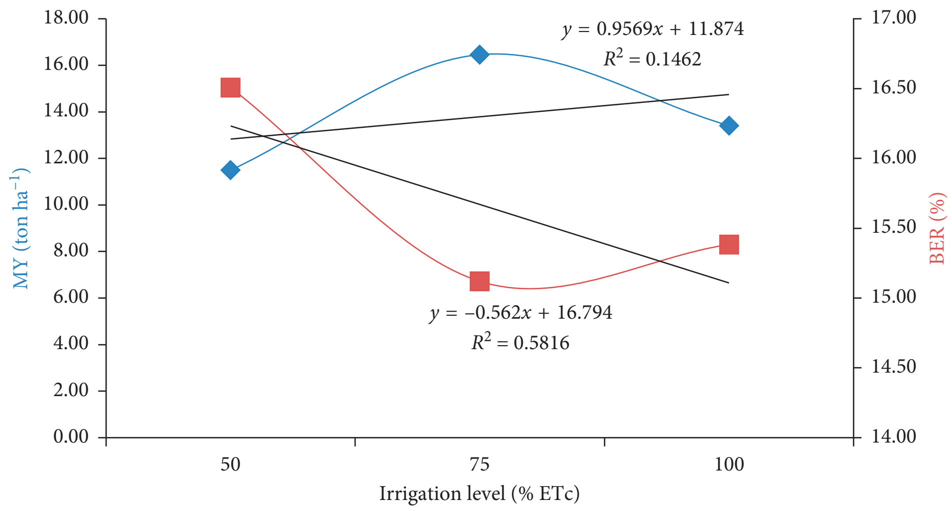


Figure 1: Relationship of irrigation water levels (% ETc) with marketable yield (MY) and BER incidence.

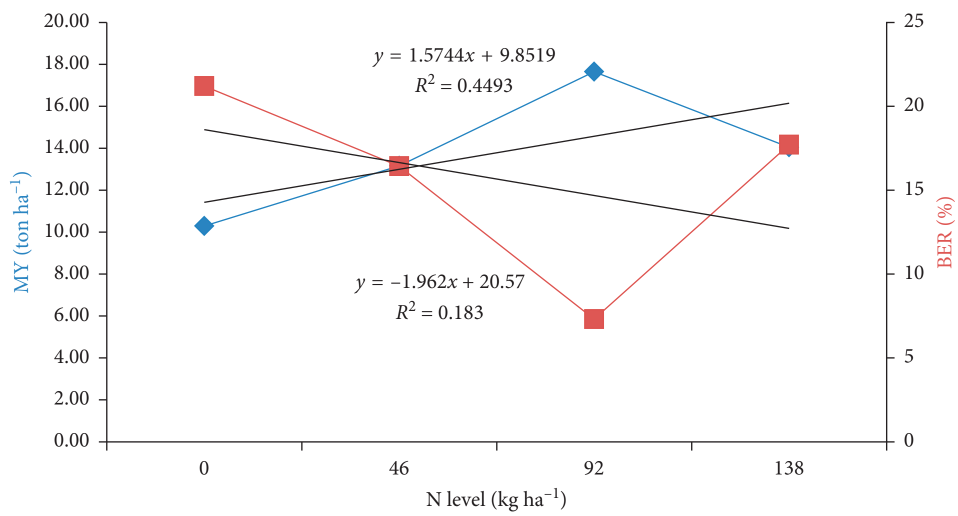


Figure 2: Relationship of nitrogen (N) levels with marketable yield (MY) and BER incidence.

Table 3: Marginal rate of return (MRR) and dominance analysis.

Treatment		Returns and costs (USD)					
		Gross income	Total varying cost	Net income	Net income over control	MRR (%)	Dominance analysis (%)
IL-1 (50% ETc)	0 kg N ha^{-1}	4,018	82	3,936	0	0	68.00
	46 kg N ha^{-1}	5,303	143	5,160	1,224	29.14	93.13
	92 kg N ha^{-1}	7,040	204	6,836	2,900	48.34	−255.70[d]
	138 kg N ha^{-1}	5,527	224	5,302	1,366	20.70	32.53
IL-2 (75% ETc)	0 kg N ha^{-1}	6,269	82	6,188	0	0.00	66.42
	46 kg N ha^{-1}	7,526	143	7,383	1,196	28.46	120.63
	92 kg N ha^{-1}	9,759	204	9,555	3,367	56.11	−338.66[d]
	138 kg N ha^{-1}	7,788	224	7,563	1,376	20.84	31.78
IL-3 (100% ETc)	0 kg N ha^{-1}	4,418	82	4,336	0	0.00	82.55
	46 kg N ha^{-1}	5,965	143	5,822	1,486	35.38	132.53
	92 kg N ha^{-1}	8,411	204	8,207	3,871	64.52	−287.88[d]
	138 kg N ha^{-1}	6,745	224	6,521	2,185	33.11	32.49

[d]Dominated treatment. USD = United States dollar.

conduct the stepwise treatment comparison (also known as dominance analysis). Result of the dominance analysis indicated that higher marginal rate or return (132.53%) was recorded from tomatoes produced under full irrigation with the application of 46 kg N ha^{-1}. In all the irrigation water levels, treatments which received 92 kg N ha^{-1} were dominated and resulted in a rate of return below the farmer's minimum acceptable rate of return (100%).

In tomato production, using full irrigation level (100% ETc), by changing the level of N application from 0 to 46 kg ha^{-1}, farmers can recover 1 USD plus an extra 1.33 USD ha^{-1} in net return for each 1 USD ha^{-1} on average invested. On the other hand, the application of 92 kg N ha^{-1} resulted in negative returns in all the irrigation levels. For tomatoes cultivated under full irrigation level, changing the N application level from 46 to 92 kg ha^{-1} makes the farmer to lose 28.89 USD ha^{-1} for each 1 USD invested. Hence, tomato production under full irrigation (100% ETc) integrated with 46 kg N ha^{-1} application rate was economically feasible practice. Comparable result was reported by Ertiban [74], who revealed application of 50 kg N ha^{-1} was economically feasible for onion production under irrigation.

Therefore, the lesson from this could be either the purchasing price of inorganic fertilizer should be decreased or else farmers are recommended to apply N at a rate of <46 kg ha^{-1}. This result contradicts with the findings of Rinaldi et al. [75], who reported the possibility to reduce irrigation level, but not N level up to 200 kg of N ha^{-1}.

4. Conclusion and Recommendation

Irrespective of the irrigation water level, tomato fruits showed higher susceptibility to incidence of BER as N fertilizer application level was below or beyond 92 kg N ha^{-1}. This implies that susceptibility of tomatoes to the incidence of BER was more due to the change in N fertilizer application levels. Based on the result of the present study, the optimum N fertilizer level that could reduce incidence of BER was 92 kg N ha^{-1}. In general, marketable fruit yields of tomato increased with an increase in irrigation water level from 50 to 75% and N rates from 0 to 92 kg ha^{-1}. From this, it can be concluded that higher fruit yield of tomato could be obtained by the application of moderate irrigation water level (75% ETc) using drip irrigation together with 92 kg N ha^{-1}. However, the partial budget analysis revealed that application of 46 kg N ha^{-1} was economically feasible irrespective of the irrigation levels. Thus, considering the current mineral fertilizer price, this is strong economic motivation for nutrient application at the grower's average rates which was 46 to 69 kg N ha^{-1}. Finally, it could be recommended that further investigation be conducted on the degree of BER incidence in relation to cations and calcium containing fertilizer applications on different tomato varieties under varying irrigation levels.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Teklay Tesfay designed field experiment, conducted data analysis, prepared manuscript, and supervised the overall project. Field data collection and manuscript review were principally conducted by Mebrahtu Gebremariam.

Acknowledgments

The authors express their sincere gratitude to Aksum University for full financial fund and for the provision of experimental field to carry out this research at Aksum University Selekleka Research and Technology Transfer Center.

References

[1] I. Antonio, F. Nigro, and L. Schenna, "Control of post harvest diseases of fresh vegetable by application of antagonistic micro-organism," in *Crop Management and Postharvest Handling of Horticultural Products*, R. Dris, R. Niskanen, and S. M. Jai, Eds., pp. 1–30, Science Publishers, New York, NY, USA, 2004.

[2] Y.-J. Sun, Y.-Y. Sun, X.-Y. Li, X. Guo, and J. Ma, "Relationship of activities of key enzymes involved in nitrogen metabolism with nitrogen utilization in rice under water–nitrogen interaction," *Acta Agronomica Sinica*, vol. 35, no. 11, pp. 2055–2063, 2009.

[3] C. Kirda, M. Cetin, Y. Dasgan et al., "Yield response of greenhouse grown tomato to partial root drying and conventional deficit irrigation," *Agricultural Water Management*, vol. 69, no. 3, pp. 191–201, 2004.

[4] M. A. Badr, W. A. El-Tohamy, and A. M. Zaghloul, "Yield and water use efficiency of potato grown under different irrigation and nitrogen levels in an arid region," *Agricultural Water Management*, vol. 110, pp. 9–15, 2012.

[5] C. Seassau, G. Dechamp-Guillaume, E. Mestries, and P. Debaeke, "Nitrogen and water management can limit premature ripening of sunflower induced by Phoma macdonaldii," *Field Crops Research*, vol. 115, no. 1, pp. 99–106, 2010.

[6] M. Gheysari, S. M. Mirlatifi, M. Homaee, M. E. Asadi, and G. Hoogenboom, "Nitrate leaching in a silage maize field under different irrigation and nitrogen fertilizer rates," *Agricultural Water Management*, vol. 96, no. 6, pp. 946–954, 2009.

[7] J. Zheng, G. Huang, J. Wang et al., "Effects of water deficits on growth, yield and water productivity of drip-irrigated onion (Allium cepa L.) in an arid region of Northwest China," *Irrigation Science*, vol. 31, no. 5, pp. 995–1008, 2013.

[8] C. M. T. Soler, G. Hoogenboom, P. C. Sentelhas, and A. P. Duarte, "Impact of water stress on maize grown off-season in a subtropical environment," *Journal of Agronomy and Crop Science*, vol. 193, no. 4, pp. 247–261, 2007.

[9] J. O. Payero, S. R. Melvin, S. Irmak, and D. Tarkalson, "Yield response of corn to deficit irrigation in a semiarid climate," *Agricultural Water Management*, vol. 84, no. 1-2, pp. 101–112, 2006.

[10] T. H. Skaggs, M. T. van Genuchten, P. J. Shouse, and J. A. Poss, "Macroscopic approaches to root water uptake as a function of water and salinity stress," *Agricultural Water Management*, vol. 86, no. 1-2, pp. 140–149, 2006.

[11] H. Gulen and A. Eris, "Effect of heat stress on peroxidase activity and total protein content in strawberry plants," *Plant Science*, vol. 166, no. 3, pp. 739–744, 2004.

[12] P. Stone, D. Wilson, J. Reid, and R. Gillespie, "Water deficit effects on sweet corn. I. Water use, radiation use efficiency, growth, and yield," *Australian Journal of Agricultural Research*, vol. 52, no. 1, pp. 103–113, 2001.

[13] Z. Chen, X. Liu, J. Niu et al., "Optimizing irrigation and nitrogen fertilization for seed yield in western wheatgrass [*Pascopyrum smithii* (Rydb.) Á. Löve] using a large multi-factorial field design," *PLoS One*, vol. 14, no. 6, Article ID e0218599, 2019.

[14] J. Y. Dang, X. X. Pei, D. Y. Zhang, J. Zhang, J. A. Wang, and M. F. Cheng, "Regulation effects of irrigation methods and nitrogen application on soil water, nitrate, and wheat growth and development," *Chinese Journal of Applied Ecology*, vol. 30, no. 4, pp. 1161–1169, 2019.

[15] C. Zongkui, T. Xianping, K. Aziz, K. Y. T. Daniel, and L. Honghai, "Biomass accumulation, photosynthetic traits, and root development of cotton as affected by irrigation and nitrogen-fertilization," *Frontiers in Plant Science*, vol. 9, no. 173, 2018.

[16] Amanullah, A. Iqbal, Irfanullah, and Z. Hidayat, "Potassium management for improving growth and grain yield of maize (*Zea mays* l.) under moisture stress condition," *Scientific Reports*, vol. 6, no. 1, 34627 pages, 2016.

[17] M. U. Bashir, S. A. Wajid, A. Ahmad, and M. Iqbal, "Potential soil moisture deficit: an alternative approach for irrigation scheduling in wheat," *International Journal of Agriculture and Biology*, vol. 18, no. 1, pp. 16–22, 2016.

[18] Y. He, L. Hou, H. Wang, K. Hu, and B. McConkey, "A modelling approach to evaluate the long-term effect of soil texture on spring wheat productivity under a rain-fed condition," *Scientific Reports*, vol. 4, no. 1, p. 5736, 2014.

[19] F. Celette and C. Gary, "Dynamics of water and nitrogen stress along the grapevine cycle as affected by cover cropping," *European Journal of Agronomy*, vol. 45, pp. 142–152, 2013.

[20] G. Mahajan, B. S. Chauhan, J. Timsina, P. P. Singh, and K. Singh, "Crop performance and water- and nitrogen-use efficiencies in dry-seeded rice in response to irrigation and fertilizer amounts in northwest India," *Field Crops Research*, vol. 134, pp. 59–70, 2012.

[21] Y. Sun, J. Ma, Y. Sun et al., "The effects of different water and nitrogen managements on yield and nitrogen use efficiency in hybrid rice of China," *Field Crops Research*, vol. 127, pp. 85–98, 2012.

[22] Y.-D. Du, H.-X. Cao, S.-Q. Liu, X.-B. Gu, and Y.-X. Cao, "Response of yield, quality, water and nitrogen use efficiency of tomato to different levels of water and nitrogen under drip irrigation in Northwestern China," *Journal of Integrative Agriculture*, vol. 16, no. 5, pp. 1153–1161, 2017.

[23] X. Wang and Y. Xing, "Evaluation of the effects of irrigation and fertilization on tomato fruit yield and quality: a principal component analysis," *Scientific Reports*, vol. 7, no. 1, p. 350, 2017.

[24] D. Djidonou, X. Zhao, E. H. Simonne, K. E. Koch, and J. E. Erickson, "Yield, water-, and nitrogen-use efficiency in field-grown, grafted tomatoes," *HortScience*, vol. 48, no. 4, pp. 485–492, 2013.

[25] M. C. Akemo, M. A. Bennett, and E. E. Regnier, "Tomato growth in spring-sown cover crops," *HortScience*, vol. 35, no. 5, pp. 843–848, 2000.

[26] R. K. Toor, G. P. Savage, and A. Heeb, "Influence of different types of fertilisers on the major antioxidant components of tomatoes," *Journal of Food Composition and Analysis*, vol. 19, no. 1, pp. 20–27, 2006.

[27] C. M. Geraldson, "The use of calcium for control of blossom-end rot of tomatoes," in *Proceedings of the Florida State Horticultural Society*, vol. 68, pp. 197–202, Jackson, TN, USA, December 1955.

[28] OARD (Office of Agriculture and Rural Development), *Medebay-Zana Office of Agriculture and Rural Development Annual Report*, 2018.

[29] FAO, *Statistical Year Book*, Food and Agriculture Organization of the United Nations, Rome, Italy, 2013.

[30] J. Warner, T. Q. Zhang, and X. Hao, "Effects of nitrogen fertilization on fruit yield and quality of processing tomatoes," *Canadian Journal of Plant Science*, vol. 84, no. 3, pp. 865–871, 2004.

[31] J. Min, X. Zhao, W.-M. Shi, G.-X. Xing, and Z.-L. Zhu, "Nitrogen balance and loss in a greenhouse vegetable system in Southeastern China," *Pedosphere*, vol. 21, no. 4, pp. 464–472, 2011.

[32] M. D. Taylor, S. J. Locascio, and M. R. Alligood, "Blossom-end rot incidence of tomato as affected by irrigation quantity, calcium source, and reduced potassium," *HortScience*, vol. 39, no. 5, pp. 1110–1115, 2004.

[33] I. C. MacSwan, *Blossom End Rot of Tomatoes*, Oregon State University Extension Service, Corvallis, OR, USA, 2000.

[34] G. Winsor and P. Adams, "Diagnosis of mineral disorders in plants," in *Glasshouse Crops*, J. B. D. Robinson, Ed., vol. 3, p. 166, Crown, London, UK, 1987.

[35] M. C. Saure, "Blossom-end rot of tomato (Lycopersicon esculentum Mill.)—a calcium- or a stress-related disorder?," *Scientia Horticulturae*, vol. 90, no. 3-4, pp. 193–208, 2001.

[36] M. Kitano, T. Araki, S. Yoshida, and T. Eguchi, "Dependence of calcium uptake on water absorption and respiration in roots of tomato plants," *Biotronics*, vol. 28, pp. 121–130, 1999.

[37] J. A. Franco, P. J. Pérez-Saura, J. A. Ferná Ndez, M. Parra, and A. L. García, "Effect of two irrigation rates on yield, incidence of blossom-end rot, mineral content and free amino acid levels in tomato cultivated under drip irrigation using saline water," *The Journal of Horticultural Science and Biotechnology*, vol. 74, no. 4, pp. 430–435, 1999.

[38] E. A. Kirby and D. J. Pilbeam, "Calcium as a plant nutrient," *Plant, Cell and Environment*, vol. 7, no. 6, pp. 397–405, 1984.

[39] L. F. M. Marcelis and L. C. Ho, "Blossom-end rot in relation to growth rate and calcium content in fruits of sweet pepper (Capsicum annuum L.)," *Journal of Experimental Botany*, vol. 50, no. 332, pp. 357–363, 1999.

[40] C. Kreij, "Interactive effect of air humidity, calcium, and phosphate on blossom end rot, leaf deformation, production, and nutrient contents of tomato," *Journal of Plant Nutrition*, vol. 19, no. 2, pp. 361–377, 1996.

[41] E. A. S. Paiva, H. E. P. Martinez, V. W. D. Casali, and L. Padilha, "Occurrence of blossom-end rot in tomato as a function of calcium dose in the nutrient solution and air relative humidity," *Journal of Plant Nutrition*, vol. 21, no. 12, pp. 2663–2670, 1998.

[42] W. Xiukang and X. Yingying, "Evaluation of the effect of irrigation and fertilization by drip fertigation on tomato yield and water use efficiency in greenhouse," *International Journal of Agronomy*, vol. 2016, pp. 1–10, 2016.

[43] X. Li, F. Liu, G. Li, Q. Lin, and C. R. Jensen, "Soil microbial response, water and nitrogen use by tomato under different irrigation regimes," *Agricultural Water Management*, vol. 98, no. 3, pp. 414–418, 2010.

[44] C. Kirda, "Deficit irrigation scheduling based on plant growth stages showing water stress tolerance," in *Deficit Irrigation Practices, Water Reports*, vol. 22, pp. 3–10, Food and Agriculture Organization of the United Nations, Rome, Italy, 2002.

[45] Y. Zhai, Q. Yang, and Y. Wu, "Soil salt distribution and tomato response to saline water irrigation under straw mulching," *PLoS One*, vol. 11, no. 11, Article ID e0165985, 2016.

[46] D. Alemneh, *Integrated Natural Resources Management to Enhance Food Security: The Case for Community-Based Approaches in Ethiopia*, Food and Agriculture Organization of the United Nations, Rome, Italy, 2003.

[47] *ENMA, National Meteorology and Statistics Agency, ENMA*, Mekelle, Ethiopia, 2018.

[48] FAO/UNESVO (Food and Agriculture Organization of the United Nations/United Nations Educational, Scientific and Cultural Organization), *Guidelines for Soil Profile Description*, Pub. No: 66, FAO, Rome, Italy, 1977.

[49] D. Raes, P. Steduto, T. C. Hsiao, and E. Fereres, "AquaCrop—the FAO crop model to simulate yield response to water: II. Main algorithms and software description," *Agronomy Journal*, vol. 101, no. 3, pp. 438–447, 2009.

[50] L. K. Heng, T. Hsiao, S. Evett, T. Howell, and P. Steduto, "Validating the FAO AquaCrop model for irrigated and water deficient field maize," *Agronomy Journal*, vol. 101, no. 3, pp. 488–498, 2009.

[51] R. G. Allen, L. S. Pereira, D. Raes, and M. Smith, *Crop Evapo-Transpiration-Guidelines for Computing Crop Water Requirements*, Irrigation and Drainage Paper, No. 56, FAO, Rome, Italy, 1998.

[52] S. Khan, S. Anwar, J. Kuai, S. Ullah, S. Fahad, and G. Zhou, "Optimization of nitrogen rate and planting density for improving yield, nitrogen use efficiency, and lodging resistance in oilseed rape," *Frontiers In Plant Science*, vol. 8, pp. 115–128, 2017.

[53] G. J. Bouyoucos, "Hydrometer method improved for making particle size analyses of soils," *Agronomy Journal*, vol. 54, no. 5, pp. 464-465, 1962.

[54] M. R. Carter, *Soil Sampling and Methods of Analysis*, Canadian Society of Soil Science, Lewis publishers, London, UK, 1993.

[55] M. Peach, "Hydrogen–ion activity," in *Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties*, C. A. Black, Ed., vol. 9, pp. 914–925, American Society of Agronomy, Madison, WI, USA, 1965.

[56] S. Olsen and L. Sommer, *Phosphorus Method for Soil Analysis; Part 2 Chemical and Microbiological Properties*, The American Society of Agronomy, Madison, WI, USA, 1982.

[57] A. Walkley and I. A. Black, "An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method," *Soil Science*, vol. 37, no. 1, pp. 29–38, 1934.

[58] CIMMYT, *From Agronomic Data to Farmer Recommendations: An Economics Training Manual (Completely Revised Edition)*, CIMMYT, Mexico City, Mexico, 1988.

[59] H. Asumadu, P. Y. K. Sallah, P. B. Boa-Amponsen, J. Allou, Manu-Adunung, and Osei-Bounsu, "On-farm evaluation and promotion of quality protein maize hybrids in Ghana," *African Crop Science Society*, vol. 4, pp. 358–364, 2004.

[60] R. J. Farquharson, "Production response and input demand in decision making: nitrogen fertilizer and wheat growers," *Australasian Agribusiness Review*, vol. 14, pp. 159–164, 2006.

[61] H. Shah, M. Sharif, A. Majid, U. Hayat, and A. Munawar, "From experimental data to farmer recommendation: an economic analysis of on-farm trial of UMMB feed for milking animals in rain-fed Pothwar, Pakistan," *Livestock Research for Rural Development*, vol. 21, no. 8, p. 117, 2009.

[62] H. Kirnak, D. Higgs, C. Kaya, and I. Tas, "Effects of irrigation and nitrogen rates on growth, yield, and quality of muskmelon in semiarid regions," *Journal of Plant Nutrition*, vol. 28, no. 4, pp. 621–638, 2005.

[63] H. S. Bhella, "Muskmelon growth, yield and nutrition as influenced by planting method and trickle irrigation," *Journal of American Society For Horticultural Science*, vol. 110, pp. 793–796, 1985.

[64] K. Srinivas, D. M. Hegde, and G. V. Havanagi, "Plant water relations, canopy temperature, yield and water-use efficiency of watermelonCitrullus lanatus(Thunb.) Matsum et Nakai under drip and furrow irrigation," *Journal of Horticultural Science*, vol. 64, no. 1, pp. 115–124, 1989.

[65] V. Candido, V. Miccolis, and A. R. Rivelli, "Yield traits and water and nitrogen use efficiencies of bell pepper grown in plastic-greenhouse," *Italian Journal of Agronomy*, vol. 4, no. 3, pp. 91–100, 2009.

[66] W. Xiukang, Y. Jia, S. Peng, L. Zhanbin, L. Peng, and X. Yingying, "Root growth, fruit yield and water use efficiency of greenhouse grown tomato under different irrigation regimes and nitrogen levels," *Journal of Plant Growth Regulation*, vol. 38, no. 2, pp. 400–415, 2019.

[67] L. D. Costa and G. Gianquinto, "Water stress and watertable depth influence yield, water use efficiency, and nitrogen recovery in bell pepper: lysimeter studies," *Australian Journal of Agricultural Research*, vol. 53, no. 2, pp. 201–210, 2002.

[68] K. Birhanu and K. Tilahun, "Fruit yield and quality of drip-irrigated tomato under deficit irrigation," *African Journal of Food, Agriculture, Nutrition and Development*, vol. 10, no. 2, pp. 2140–2151, 2010.

[69] P. M. Vitousek, R. Naylor, T. Crews et al., "Nutrient imbalances in agricultural development," *Science*, vol. 324, no. 5934, pp. 1519-1520, 2009.

[70] J. O'Sullivan, "Response of peppers to irrigation and nitrogen," *Canadian Journal of Plant Science*, vol. 59, no. 4, pp. 1085–1091, 1979.

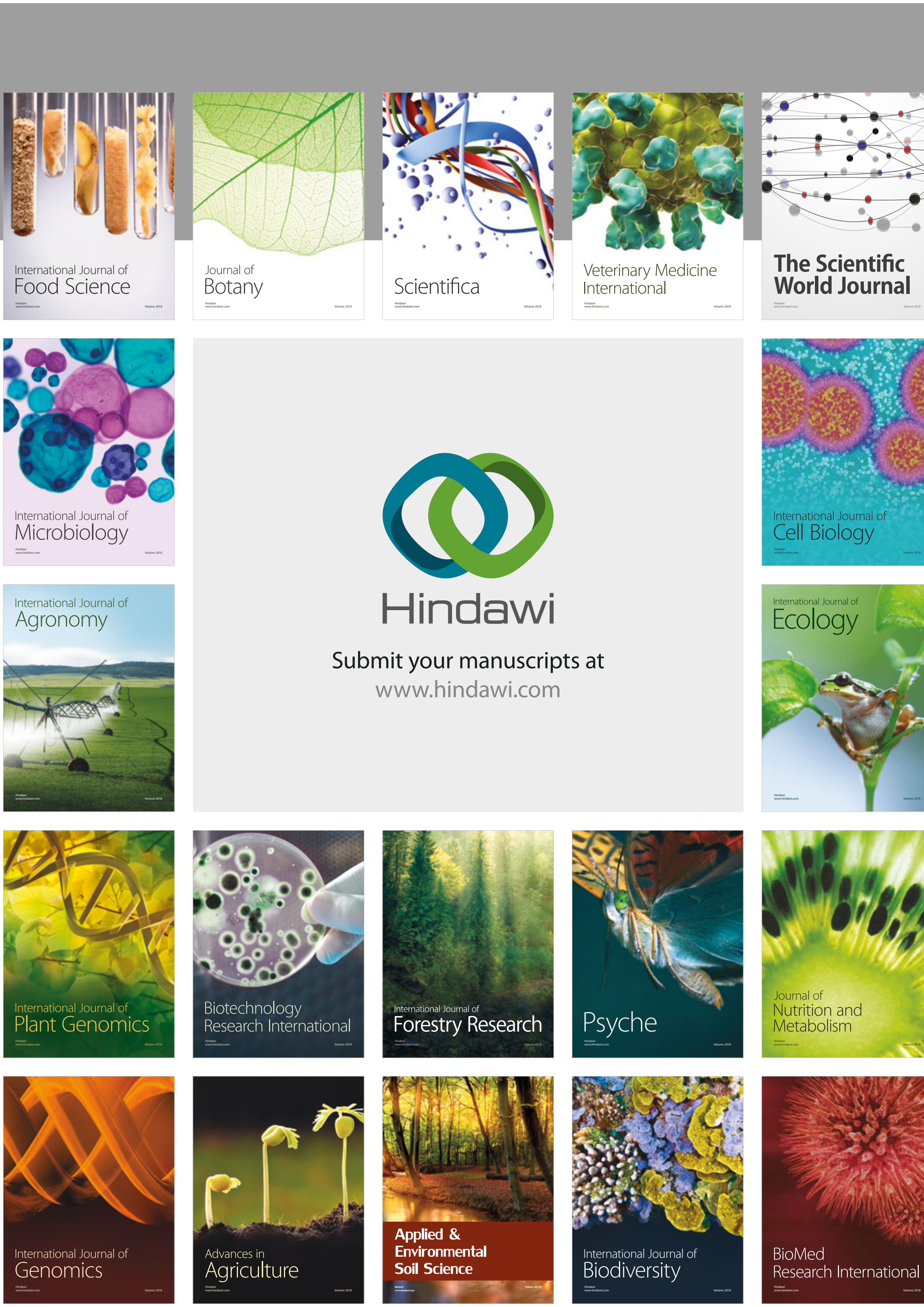
[71] D. M. May and J. Gonzales, "Irrigation and nitrogen management as they affect fruit quality and yield of processing tomatoes," *Acta Horticulturae*, vol. 376, no. 376, pp. 227–234, 1994.

[72] A. Ozbahce and A. F. Tari, "Effects of different emitter space and water stress on yield and quality of processing tomato under semi-arid climate conditions," *Agricultural Water Management*, vol. 97, no. 9, pp. 1405–1410, 2010.

[73] M. Sezen, A. Yazar, S. Tekin, S. Eker, and B. Burçak, "Yield and quality response of drip-irrigated pepper under Mediterranean climatic conditions to various water regimes," *African Journal of Biotechnology*, vol. 10, no. 8, pp. 1329–1339, 2011.

[74] W. Ertiban, "Effect of irrigations and chemical fertilizer on the yield of onion at Megech-Seraba irrigation scheme," *Nile Water Science and Engineering*, vol. 10, no. 2, pp. 41–45, 2017.

[75] M. Rinaldi, D. Ventrella, and C. Gagliano, "Comparison of nitrogen and irrigation strategies in tomato using CROPGRO model. A case study from Southern Italy," *Agricultural Water Management*, vol. 87, no. 1, pp. 91–105, 2007.


International Journal of Food Science
Journal of Botany
Scientifica
Veterinary Medicine International
The Scientific World Journal
International Journal of Microbiology
Hindawi
Submit your manuscripts at
www.hindawi.com
International Journal of Cell Biology
International Journal of Agronomy
International Journal of Ecology
International Journal of Plant Genomics
Biotechnology Research International
International Journal of Forestry Research
Psyche
Journal of Nutrition and Metabolism
International Journal of Genomics
Advances in Agriculture
Applied & Environmental Soil Science
International Journal of Biodiversity
BioMed Research International