Agricultural Research & Technology
Open Access Journal
ISSN: 2471-6774

Juniper Publishers
key to the Researchers

Research Article
Volume 11 Issue 1 - August 2017
DOI: 10.19080/ARTOAJ.2017.11.555801

Agri Res & Tech: Open Access J

Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes

Bannayan M*, Mortazagoldani and Mohammad Reza Naderi

Department of Agriculture, Ferdowsi University of Mashhad, Iran

Submission: January 13, 2017; **Published:** August 29, 2017

*Corresponding author: Mohamad Bannayan, Department of Agriculture, Ferdowsi University of Mashhad, P.O. Box 91775-1163, Mashhad, Iran, Tel: +98-511-8795616; Fax: +98-511-8787430; Email: Banayan@um.ac.ir

Abstract

Pumpkin (*Cucurbita pepo L.*) is an economically important plant and is cultivated throughout the world for oil and medicinal purposes. Optimum management practices to improve the growth and production of this forgotten crop require detailed growth data and analysis. This study was conducted to investigate the impacts of different management practices (including sowing date, plant density and nitrogen application) and temperature regimes on growth parameters of pumpkin, including shoot dry weight (DW), radiation use efficiency (RUE) and intercepted PAR (PAR_i). The required data of pumpkin were collected from a four-year experiment (2010, 2012, 2013 and 2014) which performed at research farm of Ferdowsi university of Mashhad, Iran. Results showed that sowing date between 1-11 May, plant density of 2.5 plants m^{-2} and nitrogen rate of 250kgha^{-1} resulted in highest possible yield of pumpkin. Increasing of both radiation use efficiency and intercepted PAR increased the pumpkin dry weight. Temperature stress induced by delaying sowing date resulted in lower pumpkin growth, however negative impact of temperature stress can be alleviated through selecting the optimum sowing date. Different temperature regimes during various phases of pumpkin growth cycle also led to the intra and inter annual variation of pumpkin dry weight among different sowing dates and years. Under optimum nitrogen rate, pumpkin showed improved resistance to higher air temperature. The study revealed the role of optimum nitrogen rate on decreasing impacts of temperature stress on crop growth.

Keywords: Sowing date; Plant density; Nitrogen rate; Temperature stress

Introduction

Agricultural systems are characterized by the interdependency and complexity of their components, by variability in surrounding environment and risk involved in their management [1]. In an agricultural system, plant growth and development are dependent upon the integrated responses of various interacting variables (temperature, CO_2, nutrients, water, and agronomic management) through various eco-physiological processes [2]. Increasing environmental degradation in agricultural fields, in the form of declining soil fertility, lowering water tables, rising salinity, increasing resistance to pesticides, and degradation of irrigation water quality [3], rising temperatures and carbon dioxide, and uncertainties in rainfall associated with global climatic change may impact food production [4] and farmers income [1].

Recent climate trends had negative impacts on global yield levels of widely grown crops [5]. Therefore, one of the main topics in agronomic research is to find management strategies that maximize crop production and minimize environmental degradation [6]. To abate the negative impacts of climatic change, the adaptation of agricultural practices will play a decisive role [7]. Agricultural production can benefit already from small changes at the tactical level such as adjustments in sowing date, fertilization intensity [5] and plant density. Sowing date is one of the most important management factor affecting crop production and quality [8]. In a given region, the optimum sowing date depends mainly upon the timing of rainfall [9]. In most cases, delaying sowing beyond the optimum period reduces crop growth and yield [10,11] due to increasing temperatures and diminishing moisture conditions [12,13]. Therefore, selecting the optimum planting date can be considered as an adaptation response to climate change [14].

Nitrogen plays an important role in plant growth [15]. This nutrient is a component of protein and nucleic acid and when N amount in soil is not optimal, growth is reduced [15]. Optimum nitrogen rate enhances crop growth by increasing leaf area index (LAI), intercepted photo synthetically active radiation [16] and radiation use efficiency (RUE). Whereas, yield and growth reduction is often observed under excessive input due to greater pest incidence, disease damage [17] and too much accumulation of metabolites such as nitrates, amides, and free amino acids which can be toxic for crop growth in excessive levels [18]. Thus, by optimizing the N fertilizer inputs, not only crop requirements can be met, but the environmental problems such as nitrate leaching to ground water and greenhouse gas emissions also can be decreased. Other important management factor that influences crop growth and yield is plant density. Maximum crop growth and yield is achieved at optimum plant density which depends upon cropping system, environmental condition and cultivar [19-21].

Crop growth and yield is the result of the interactions between genotype (cultivar characteristics), environment (climate and soil conditions), and management [22]. Climate is one of the key components that control agricultural production [23]. Despite ongoing improvements in technology and crop varieties, climate is still the main uncontrollable factor affecting agricultural production [24]. In some cases, as much as 80% of the variability of agricultural production was reported due to the variability in climate conditions [23,25]. Thus, Crop growth and yield are affected by variations in climatic factors such as air temperature and precipitation, and the frequency and severity of extreme events such as droughts, floods, hurricanes, windstorms and hail [23,25,26].

The critical agro meteorological variables associated with crop growth are precipitation, air temperature, and solar radiation which among them, air temperature is the main weather variable that regulates the rate of vegetative and reproductive development [27-29]. In most cases, an increase in temperature increases the developmental rate. At extremely high temperatures, the inverse occurs, and developmental rates slow down as the temperature further increases [23]. Temperature is one of the key determinants of potential productivity for crops grown under well-watered conditions with adequate nutrients in the absence of limitations caused by weeds, pests or diseases [15]. Temperature is also a key determinant of evaporative and transpirative demand [30]. Under field conditions, crop growth is found to be related to conversion efficiency of intercepted radiation energy into dry matter, which is called radiation use efficiency (RUE) [31]. Furthermore, many experiments showed that crop yield was positively related to RUE [32-35]. Inadequate biomass production due to decreased RUE was considered as a major limitation to crop yield [36]. Management practices and climatic variations resulting from seasonal and annual fluctuations can affect radiation use efficiency and thus crop growth and yield [37,38]. Therefore, by evaluating the effect of various management practices and important weather variables on radiation use efficiency and growth of crop, optimum management practices which can increase final crop yield are determined.

Pumpkin (*Cucurbita pepo L.*) is an economically important plant and is cultivated throughout the world for oil and medicinal products [39] and its importance as an economical and medicinal plant is becoming increasingly apparent. It is rich in nutrients and bioactive compounds contents such as phenolics, flavonoids, vitamins, amino acids, carbohydrates and minerals (especially potassium), and it is low in energy content (about 17Kcal/100g of fresh pumpkin) and has large amount of fiber [40]. It has various medicinal effects comprising anti diabetic, antihypertensive, antitumor, antimutagenic, immune modulating, antibacterial, anti-hyper cholesterolemic, intestinal anti-parasitic, antalgic, and anti inflammation effects [41]. However, there has been relatively little research to systematically describe pumpkin growth [42]. Thus, it is tried in this study to analysis the influence of some management practices and climate variables (including temperature, solar radiation and precipitation) on growth of pumpkin under field conditions using the data of four years experiment.

Materials and Methods

Growth data

The growth data of pumpkin were collected from four years experiments which have been conducted in 2010, 2012, 2013 and 2014 at the research farm of Ferdowsi university of Mashhad, Iran (with latitude 36°16′ N, longitude 59° 38′ E, elevation 999m, annual average of minimum temperature 8.3 °C, annual average of maximum temperature 21.6 °C and total precipitation of 256.5mm [43]. The study location is showed in Figure 1. Furthermore, details of the treatments employed in each experiment are presented in Table 1.

Figure 1: The geographical location of Mashhad on Iran's map.

How to cite this article: Bannayan M, Mortazagoldani, Mohammad R N.Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes. Agri Res & Tech: Open Access J. 2017; 11(1): 555801. DOI: 10.19080/ARTOAJ.2017.11.555801.

Table 1: Employed treatments in four years experiments.

Experiment	Sowing date	Treatments	Identification Code
2010	May 1	150kg N ha^{-1} and 0.625 plant m^{-2}	T1-2010
		150kg N ha-1 and 1.25 plant m^{-2}	T2-2010
		150kg N ha^{-1} and 2.5 plant m^{-2}	T3-2010
		250kg N ha^{-1} and 0.625 plant m^{-2}	T4-2010
		250kg N ha^{-1} and 1.25 plant m^{-2}	T5-2010
		250kg N ha^{-1} and 2.5 plant m^{-2}	T6-2010
		350kg N ha^{-1} and 0.625 plant m^{-2}	T7-2010
		350kg N ha^{-1} and 1.25 plant m^{-2}	T8-2010
		350kg N ha^{-1} and 2.5 plant m^{-2}	T9-2010
2012	May 1, May 11 and May 21	Sowing date May 1 and 2.5 plant m^{-2}	T1-2012
		Sowing date May 1 and 4 plant m^{-2}	T2-2012
		Sowing date May 11 and 2.5 plant m^{-2}	T3-2012
		Sowing date May 11 and 4 plant m^{-2}	T4-2012
		Sowing date May 21 and 2.5 plant m^{-2}	T5-2012
		Sowing date May 21 and 4 plant m^{-2}	T6-2012
2013	May 6	50kg N ha^{-1} with plant density of 2.5 plant m^{-2}	T1-2013
		150kg N ha^{-1} with plant density of 2.5 plant m^{-2}	T2-2013
		250kg N ha^{-1} with plant density of 2.5 plant m^{-2}	T3-2013
2014	May 6	50kg N ha^{-1} with plant density of 2.5 plant m^{-2}	T1-2014
		150kg N ha^{-1} with plant density of 2.5 plant m^{-2}	T2-2014
		250kg N ha^{-1} with plant density of 2.5 plant m^{-2}	T3-2014

In the first year of experiment (2010), treatments (including nitrogen application and plant density) were arranged using a split plot design in the form of completely randomized block with three replications. Nitrogen application as the main plot was carried out in three levels including 150, 250 and 350kgha^{-1} (using urea containing 46% Nitrogen) and plant density as the sub-plot was performed in three levels including 2.5, 1.25 and 0.625 plant m^{-2}. For the plant densities of 2.5, 1.25 and 0.625 plant m^{-2}, within row space was 20, 32 and 64cm, respectively. The size of each plot was 10m×6m and between rows distance was considered 2m with a 50cm furrow for each row. The seed bed preparation was carried out using the common practices (including plow, disk and leveler) and sowing was performed at May 1. The furrow irrigation was employed in order to supply the water requirement of plants and first irrigation was carried out immediately after sowing and other irrigations were performed weekly. Furthermore, the first portion of urea fertilizer (one-third of the amount required for each treatment) was applied two weeks after sowing and the second fertilization (two-third of the amount required for each treatment) was accomplished 6 weeks after sowing. In each time of fertilization, the nitrogen fertilizer was band-dressed on the planted side of furrow. During the season, weeds were controlled manually. Destructive samplings were carried out six times at different dates during the growth season in order to cover the various developmental stages of this crop. The first sampling was performed 27 days after planting and other samplings were accomplished with an interval of 15 days. In each sampling, three plants were randomly harvested from each plot and after measuring the green leaf area using a leaf area meter (LI-3100), the shoot of each plant were separately dried at 75 °C for 72h. The average of shoot dry weight obtained from three plants of each plot was considered for that plot and the average of dry weight obtained from three plots of each treatment was considered for that treatment.

In the second experiment (2012), treatments (including sowing date and plant density) were arranged using a split plot design in the form of completely randomized blocks with three replications. Sowing date as the main plot was employed in three levels including May 1, May 11 and May 21 and plant density as the sub-plot was performed in two levels including 2.5 and 4 plant m^{-2}. The size of each plot was 10m×5 m and between rows distance was considered 2m with a 0.5m furrow for each row. The seedbed was prepared using the common practices (including plow, disk and leveler) and seeds were sown on 1, 11 and 21 of May. For the plant densities of 2.5 and 4 plant m^{-2}, the between row space was 20and 10cm, respectively. The furrow irrigation was employed in order to supply the water requirement of plants and first irrigation was carried out immediately after sowing and other irrigations were performed on weekly basis. During the growing season no fertilizer was applied and weed control was performed by hand weeding. Similar to 2010 experiment, the destructive samplings during the growing season were performed at different dates in order to cover the various developmental stages of pumpkin. Accordingly, six destructive

How to cite this article: Bannayan M, Mortazagoldani, Mohammad R N.Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes. Agri Res & Tech: Open Access J. 2017; 11(1): 555801. DOI: 10.19080/ARTOAJ.2017.11.555801.

samplings were carried out during the growth of pumpkin. Initial sampling for the first (May 1), second (May 11) and third (May 21) sowing dates was conducted 20, 25 and 29 days after sowing, respectively, and other samplings were performed with an interval of 14 days. In each sampling, three plants were randomly harvested from each plot and after measuring the green leaf area using a leaf area meter (VM-900), the shoot of each plant were separately dried at 75 °C for 72h.

In 2013 and 2014 experiments, the seedbed preparation was carried out using the common practices (including plow, disk and leveler) and pumpkin plants were seeded at 6-May with density equal to 2.5 plant m^{-2}. The plot size was 15m×5m and in each plot, 6 planting lines with a 2m row spacing and 50cm furrow between each line were considered. The furrow irrigation was employed in order to supply the water requirements of pumpkin plants and first irrigation was carried out immediately after sowing and other irrigations were performed on weekly basis. During the growing season of pumpkin, weed control was performed by hand weeding. Treatments were included three levels of nitrogen application (including 50, 150 and 250kgha^{-1} using urea fertilizer containing 46% Nitrogen), which were arranged according to the design of completely randomized blocks with four replications. In both years, the first portion of urea fertilizer (half of the total) was applied four weeks after sowing (coinciding with 4-6 leaf stage) and the second fertilization (the second half) was used 6 weeks after sowing (coinciding with flowering stage). In order to apply nitrogen after irrigation, the urea fertilizer was band-dressed on the planted side of each furrow. Five destructive samplings were carried out during the crop growth cycle, starting from 30 days after planting and others were taken 42, 56, 70 and 77 days after planting. Sampling were arranged in order to coincide the sampling with developmental stages of pumpkin. In each sampling, three plants were randomly harvested from second and fifth lines of each plot and after measuring the green leaf area by a leaf area meter (LI-3100), the shoot of each plant was dried at 75 °C for 72h. After drying, the shoot samples were weighted using a digital balance with accuracy of 0.001g. Then, the average of three plants harvested from each plot was considered for that plot and the average of four replications of each treatment was recorded for corresponding treatment.

Leaf Area Duration (LAD)

The leaf area duration (LAD) was calculated using Eq. (1).

$$LAD\,(\mathrm{m}^2.\mathrm{day}) = \left(\frac{LA_1 + LA_2}{2}\right) \times (t_2 - t_1) \quad (1)$$

Where LA_1 and LA_2 are the leaf area (m^2) attimes of t_1 and $_{t2}$, respectively.

Radiation Use Efficiency (RUE)

The radiation use efficiency was calculated by the following

$$RUE\,(\mathrm{g\,MJ^{-1}}) = \frac{\text{Shoot dry matter } (\mathrm{g\,m^{-2}})}{\text{Cumulative intercepted PAR } (\mathrm{MJ\,m^{-2}})} \quad (2)$$

The Angstrom model (Eq.(3)) was employed in order to calculate the global solar radiation (R_s) [45] from sunshine hours:

$$R_s = R_a\left(A + B\left(\frac{n}{N}\right)\right) \quad (3)$$

Where RS is daily global radiation (MJ m^{-2} d^{-1}), RA is daily extra-terrestrial radiation (MJ m^{-2} d^{-1}), A and B are empirical coefficients (for Mashhad, A=0.3 and B=0.37, [46]), n is sunshine duration (h) and N is the astronomical daylength (h) [45]. Global solar radiation was multiplied by 0.45 to obtain global PAR (PAR_0) [47]. Finally, the intercepted PAR (PARi) was determined according to Eq.(4) [48].

$$PAR_i = (1-\rho)PAR_0(1-e^{-kLAI}) \quad (4)$$

Where ρ is canopy reflection coefficient (ρ=0.07, [49]), k is light extinction coefficient of canopy (for pumpkin=0.72, [44]) and LAI is leaf area index. On days where LAI was not measured, the PAR_i was estimated by linear interpolation between measured values.

Table 2: Monthly weather data for 2010, 2012, 2013 and 2014 growing seasons.

Year	Month	T_{av}g (oC)a	T_{max} (oC)	T_{min} (oC)	P (mm)	Rs (MJ m^{-2} d^{-1})
2010	May	21.9	28.8	14.9	39.2	22.3
	June	27.4	35.5	19.3	4.5	26.8
	July	28.6	36.3	20.9	0.0	27.3
	August	26.4	34.5	18.2	0.0	25.5
2012	May	20.9	28.0	13.9	18.4	23.1
	June	26.0	33.3	18.7	9.5	26.4
	July	28.8	36.2	21.5	0.0	26.7
	August	27.3	35.4	19.2	0.0	25.4
2013	May	20.9	28.0	13.6	26.8	24.3
	June	26.7	33.9	19.5	0.4	25.9
	July	28.7	36.1	21.3	0.0	26.8
	August	25.9	33.0	18.8	2.4	24.0

How to cite this article: Bannayan M, Mortazagoldani, Mohammad R N.Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes. Agri Res & Tech: Open Access J. 2017; 11(1): 555801. DOI: 10.19080/ARTOAJ.2017.11.555801.

2014	May	22.9	30.2	15.5	27.1	23.5
	June	27.1	34.8	19.3	4.0	26.5
	July	28.0	35.6	20.3	0.0	27.2
	August	27.4	35.5	19.3	0.0	25.1

aT_{avg}, T_{max}, and T_{min} are average, maximum, and minimum temperatures, respectively, P is monthly total precipitation, RH_{avg} is monthly average of relative humidity and R_s is monthly average of solar radiation.

Weather data

Daily weather data of each growing season were obtained from meteorological station of Mashhad. Study weather variables consisted of daily average of temperature, daily minimum and maximum temperature, solar radiation and precipitation. Solar radiation (R_s) for each day was calculated by Angstrom model (Equation 2) using daily sunshine hours. The monthly average of weather variables for 2010, 2012, 2013 and 2014 growing seasons are presented in Table 2. Growing degree days (GDD) also was calculated as follows.

$$GDD = \sum_{1}^{n}\left(\frac{T_{max} + T_{min}}{2}\right) - T_b \quad (5)$$

Where T_{max} and T_{min} are daily maximum and minimum air temperature and T_b is base temperature of pumpkin (Tb=10; Smith, 1997). If $[(T_{max}+T_{min})/2] < Tb$, then $[(T_{max}+T_{min})/2] = T_b$ [50].

Statistical analysis

Analysis of variance (ANOVA) and mean comparsion for the effect of nitrogen rate, plant density and interaction of them on pumpkin shoot dry weight and radiation use efficiency (RUE) were conducted using SAS 9.1 and MSTAT-C softwares. Treatment effects on pumpkin shoot dry weight and radiation use efficiency (RUE) were compared through the least significant difference (LSD) test at P < 0.05. Curve fitting for regression analysis was also carried out using Sigma Plot version 11.0. Correlation coefficients represented by R^2 and were signified using P-value.

Results and Discussion

Management practices

2010 experiment: In 2010 experiment, the effect of different nitrogen rates (including 150, 250 and 350kgha^{-1}) and plant densities (including 0.625, 1.25 and 2.5plant m^{-2}) was evaluated using a split plot design with three replications. Analysis of variance for the effect of nitrogen rate, plant density and their interaction on pumpkin's maximum dry weight (DW_{max}), maximum radiation use efficiency (RUE_{max}) and intercepted photo synthetically active radiation (PAR_i) is presented in Table 3. The effect of nitrogen rate and plant density on these growth traits (i.e. DW_{max}, RUE_{max} and PAR_i) was significant at probability level of 0.01 (P≤0.01) (Table 3). The interaction between nitrogen rate and plant density had a highly significant effect (P≤0.01) on DWmax and PAR_i, while its effect on RUEmax was significant (P ≤ 0.05) (Table 3). Furthermore, analysis of variance showed that effect of plant density on all traits was more pronounced than the effect of nitrogen rate (Table 3). Thus, pumpkin growth was more sensitive to the changes in plant density rather than changes in nitrogen application. Pumpkin is a creeping crop with indeterminate growth habit which its growth and yield can be highly influenced by plant density [51].

Table 3: Analysis of variance for the effect of experimental treatments and their interaction on pumpkin's maximum dry weight (DWmax), maximum radiation use efficiency (RUE_{max}) and intercepted PAR (PAR_i) in 2010 experiment.

Source of Variation	Degree of Freedom	Sum of Squares		
		DW_{max}	RUE_{max}	PAR_i
Nitrogen rate (N)	2	45490.83**	0.12**	28261.34**
Plant density (D)	2	527259.07**	2.67**	150380.43**
N×D	4	11950.70**	0.09*	3746.33**
Error	12	2739.98	0.09	1096.10
CV (%)		4.61	6.16	3.59

* and ** are significant at probability level of 0.05 and 0.01, respectively.

Nitrogen rate had a quadratic effect on all growth traits of pumpkin (Figure 2). Accordingly, all three growth traits evaluated in this study (including DW_{max}, RUE_{max} and PAR_i) increased as the nitrogen rate increased from 150kgha^{-1} to 250kgha^{-1} (Figure 2). Whereas, with increase in nitrogen rate from 250kgha^{-1} to 350kgha^{-1}, the amount of all traits were decreased (Figure 2). Thus, the highest amount of pumpkin's DW_{max}, RUE_{max} and PAR_i was obtained by applying 250kg N ha^{-1} (Figure 2). These results clearly showed that optimum nitrogen rate (250kgha^{-1}) can increase the pumpkin growth through increasing the radiation use efficiency and intercepted PAR, while nitrogen deficiency (150kgha^{-1}) or excess (350kgha^{-1}) can be resulted in growth suppression of pumpkin due to reduction of the crop RUE and PARi. Previous studies also found that RUE was significantly reduced by application of non-optimum rate of nitrogen, such as maize, rice, and winter oilseed rape [52,53]. The reduction

How to cite this article: Bannayan M, Mortazagoldani, Mohammad R N.Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes. Agri Res & Tech: Open Access J. 2017; 11(1): 555801. DOI: 10.19080/ARTOAJ.2017.11.555801.

in biomass production in response to non-optimum N rate is associated with either a reduction in total radiation intercepted by the canopy, or by a decrease in the efficiency with which the intercepted radiation is used to produce dry matter (i.e. RUE), or a combination of both [54].

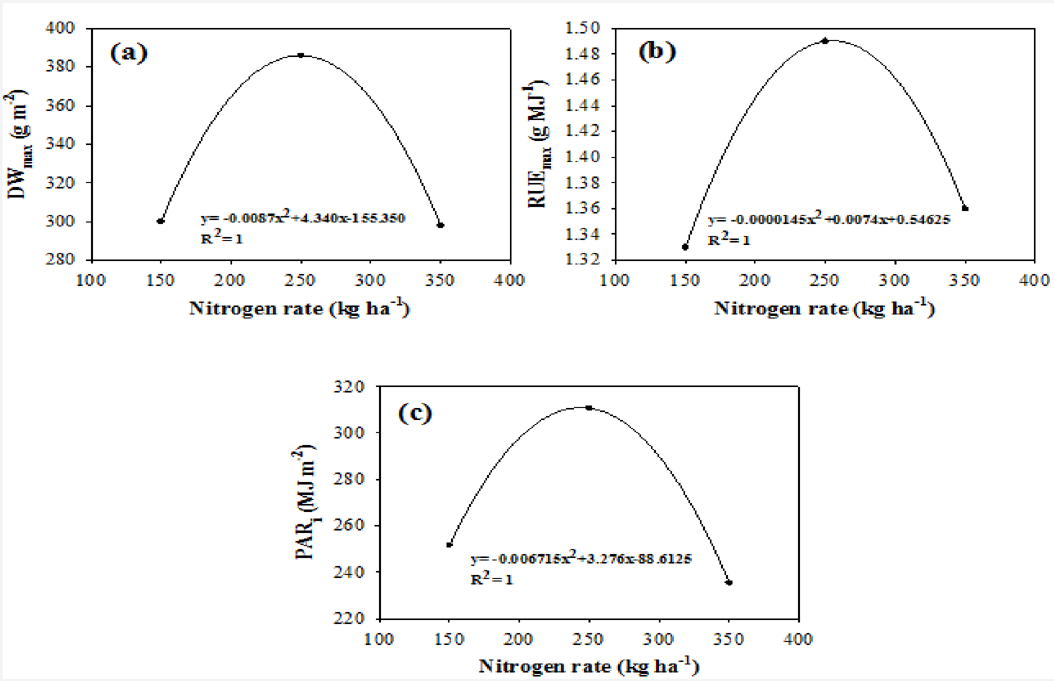

Figure 2: Effect of nitrogen rate on (a) maximum dry weight (DW_{max}), (b) maximum radiation use efficiency (RUE_{max}) and (c) intercepted PAR (PAR_i) of pumpkin in 2010 experiment.

High rate of nitrogen application is required for obtaining the optimum growth and yield of pumpkin [55]. Gholipoori et al. [56] reported that maximum growth and yield of pumpkin was obtained at nitrogen rate of 200kg ha^{-1}. Swiader and Moor [57] also were evaluated the effect of different nitrogen rates (i.e. 0, 84, 168, 252 and 336kgha^{-1}) on growth and yield of pumpkin (*C. pepovarmachuata*) under dry-land and irrigated conditions. These authors concluded that under irrigated conditions, increasing nitrogen rate to 252kgha^{-1} was led to increase in pumpkin growth and yield compared to control. Furthermore, by increasing nitrogen rate to 336kgha^{-1}, the pumpkin growth and yield was decreased compared to the optimum treatment (i.e. 252kgNha^{-1}).

Under conditions of optimal nitrogen supply, nitrogen concentration in the plant tissue reaches an optimal value and the plant attains its maximum growth [6]. Whereas, nitrogen-deficiency limits crop growth [58] and nitrogen excess adversely affects crop growth through excessive accumulation of toxic levels of Nmetabolites in the plant [18]. Similar to the results obtained in this study, a numerous studies conducted with different crop species showed that optimum N application increases crop growth, radiation use efficiency (RUE) and intercepted radiation [9,59,60-62]. For example, Justes et al. [59] reported that maximum growth, RUE and absorbed PAR of winter oilseed rape was obtained by application of 270kgNha-1, where nitrogen was non-limiting [60,61]. Furthermore, these authors also reported that N deficiencies significantly reduced the aerial dry matter, green leaf area index (LAI), radiation use efficiency and absorbed PAR of winter oilseed rape. Similarly, Fletcher et al. [62] found that shoot dry weight, RUE, LAI and PAR capture of wheat, forage rape and forage sorghum were reduced in response to N shortage. Furthermore, accumulation of nitrates, amides and free amino acids which excessive levels of them are considered to be toxic for crop growth [18] was reported in corn and wheat as a result of excess use of nitrogen [63,64].

All growth traits of pumpkin (including DW_{max}, RUE_{max} and PAR_i) were responded to the different plant densities in a sigmoidal manner (Figure 3). This sigmoidal trend shows that maximum DW (DW_{max}), maximum RUE (RUE_{max}) and intercepted PAR (PAR_i) of pumpkin were increased as the plant density increased and the highest amount of all pumpkin growth traits was obtained using the plant density of 2.5 plant m^{-2} (Figure 3). Since crop growth is dependent on light interception and also on radiation use efficiency (RUE) [65], the higher shoot dry weight of pumpkin observed at plant density of 2.5 plant m^{-2} was related to its effect on increasing pumpkin RUE and PARi (Figure 3b & 3c). Whereas, at plant densities lower than 2.5 plant m^{-2} (i.e. 0.625 and 1.25 plant m^{-2}), decreased RUE and PAR_i was led to decline in pumpkin dry weight (Figure 3b & 3c). Similarly, Mao et al. [66] studied the effect of plant density on light interception and light use efficiency of intercropped cotton. They reported that both light interception and light use efficiency of intercropped cotton were significantly increased by higher plant density. However, the effect of higher plant densities on pumpkin growth

How to cite this article: Bannayan M, Mortazagoldani, Mohammad R N.Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes. Agri Res & Tech: Open Access J. 2017; 11(1): 555801. DOI: 10.19080/ARTOAJ.2017.11.555801.

was less than lower plant densities (Figure 3). For example, with increasing plant density from 0.625 to 1.25 plant m^{-2}, the DW_{max} of pumpkin was increased by 217.3g m^{-2}, while increasing plant density from 1.25 to 2.5 plant m^{-2} was caused to an increase in $DW_{ma}x$ of pumpkin by 120.4g m^{-2} (Figure 3a). At higher plant densities, overlapping of leaves makes that photosynthesis is no longer linearly proportional to the plant population [67].

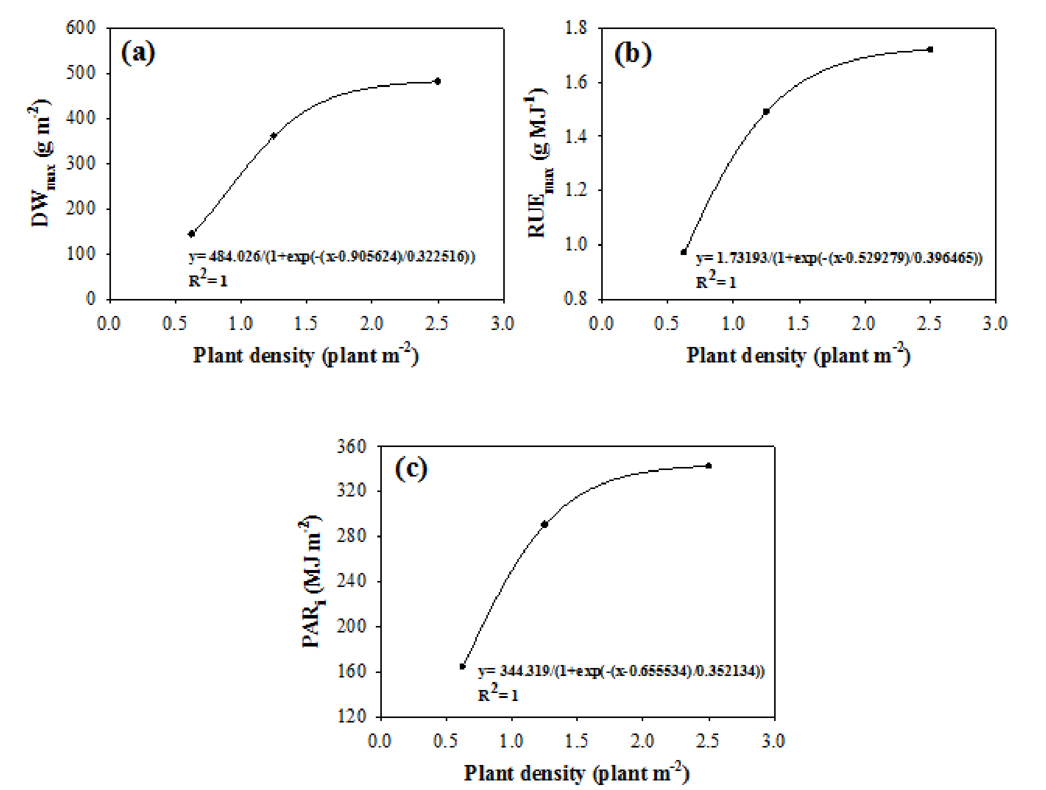

Figure 3: Effect of plant density on (a) maximum dry weight (DW_{max}), (b) maximum radiation use efficiency (RUE_{max}) and (c) intercepted PAR (PAR_i) of pumpkin in 2010 experiment.

In accordance with the results obtained in this experiment, Shabahang et al. [51]which evaluated the effect of two intra row spaces (including 20 and 40cm) and also two inter row spaces (including 100 and 200cm) on growth and yield of pumpkin concluded that highest growth and yield of pumpkin was obtained by applying 200×20cm inter and intra row spaces, respectively (i.e. plant density of 2.5 plant m^{-2}). Ebadi et al. [68] also studied the effect of three levels of plant density (including 1.85, 0.93 and 0.62 plant m^{-2}) on growth and seed and fruit yield of pumpkin. These authors reported that dry weight and seed and fruit yield of pumpkin were increased as the plant density increased and highest growth and yield of pumpkin were obtained at plant density of 1.85 plant m^{-2}. Douglas et al. [69] compared different plant densities between 0.2 and6.2 plant m^{-2} for squash (*Cucurbitamaxima*). In their study, total fruit yield increased with increasing plant density to 3.0 plant m^{-2} and then declined. Buwalda and Freeman [70] recorded growth and development of an F1 hybrid kabocha squash at a density of 2 plant per m^2. This plant density produced high growth and yield at different sowing dates. In Broderick's study [71], fruit yield of a bush cultivar of *C. maxima* squash increased as plant density increased from 0.54 to2.2 plants per m^2. Maximum fruit yield was achieved at the highest plant density (2.2plant m^{-2}), which produced a maximum aboveground dry weight.

The interaction between nitrogen rate and plant density showed that for all three nitrogen levels (i.e. 150, 250 and 350kgha^{-1}), DW_{max}, RUE_{max} and PAR_i of pumpkin were responded to the plant density in a sigmoidal manner and 100% of changes in pumpkin DW_{max} and RUE_{max} can be explained by the functions obtained (Figure 4). For all levels of plant density (including 0.625, 1.5 and 2.5 plant m^{-2}), amount of DW_{max}, RUE_{max} and PAR_i was increased by increasing the nitrogen rate to 250kgha^{-1} and then, with higher application of nitrogen (350kgNha^{-1}), both traits were decreased (Figure 4). Furthermore, for all nitrogen rates, with increasing the plant density, all growth parameters of pumpkin were increased non-linearly and maximum amount of dry weight, radiation use efficiency and intercepted PAR was obtained at plant density of 2.5 plant m^{-2} (Figure 4). Therefore, the highest amount of pumpkin DW_{max}, RUE_{max} and PAR_i was achieved by using the nitrogen rate of 250kgha-1 and plant density of 2.5 plant m-2. Accordingly, the amount of DW_{max}, RUE_{max} and PAR_i obtained by applying the optimum growth conditions (i.e. nitrogen rate of 250kgha^{-1} and plant density of 2.5 plant m^{-2}) was 575.60g m^{-2}, 1.91g MJ^{-1} and 393.30MJm^{-2}, respectively.

How to cite this article: Bannayan M, Mortazagoldani, Mohammad R N.Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes. Agri Res & Tech: Open Access J. 2017; 11(1): 555801. DOI: 10.19080/ARTOAJ.2017.11.555801.

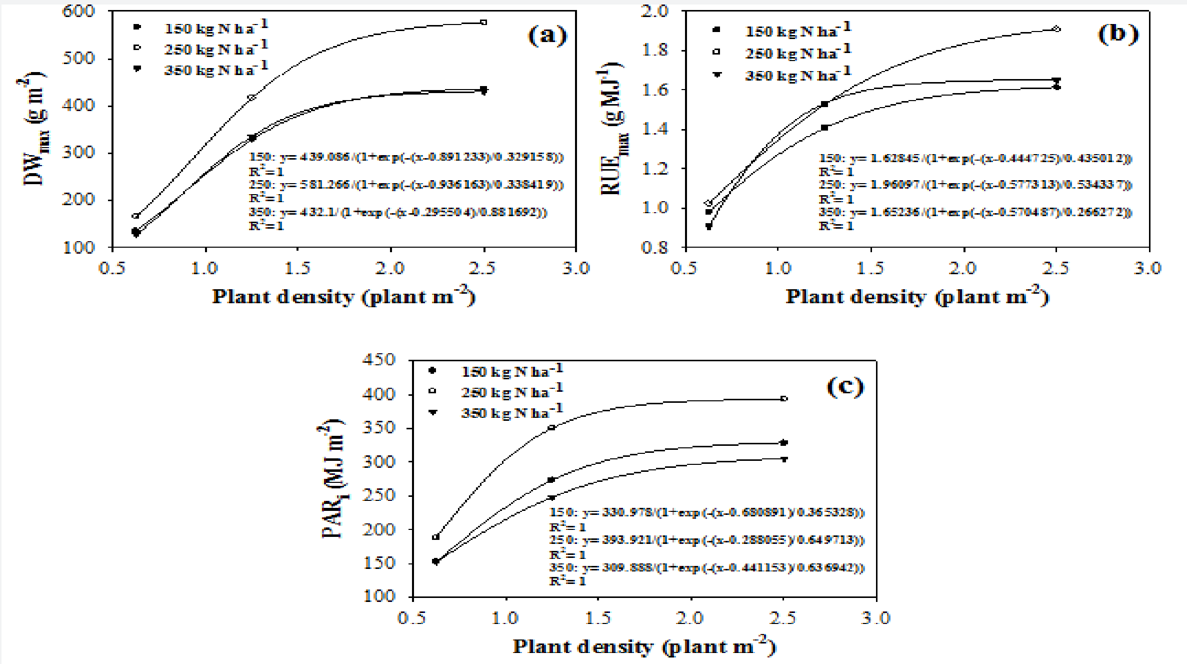

Figure 4: Effect of interaction between nitrogen rate and plant density on (a) maximum dry weight (DW_{max}), (b) maximum radiation use efficiency (RUE_{max}) and (c) intercepted PAR (PAR_i) of pumpkin in 2010 experiment.

There was a linear relationship between maximum dry weight (DW_{max}) of pumpkin and its maximum radiation use efficiency (RUE_{max}) (Figure 5a) and intercepted PAR (PAR_i) (Figure 5b). This linear relationship indicates that pumpkin dry weight was increased with increasing its radiation use efficiency and intercepted PAR (Figure 5). Therefore, under conditions of optimum nitrogen rate and plant density (i.e. nitrogen rate of 250kgha^{-1} and plant density of 2.5 plant m-2, T6-2010 treatment), increased radiation use efficiency and intercepted PAR caused to the production of highest shoot dry weight of pumpkin compared to other treatments. Previous studies also showed that a higher dry matter production resulted from optimum growth conditions is related to the more solar radiation being intercepted, higher RUE, or a combination of the two [72,73]. In return, for treatments which their nitrogen rate, plant density or both of them was lower or higher than optimum ones, the fewer dry weight was related to the lower RUE and PAR_i (Figure 5).

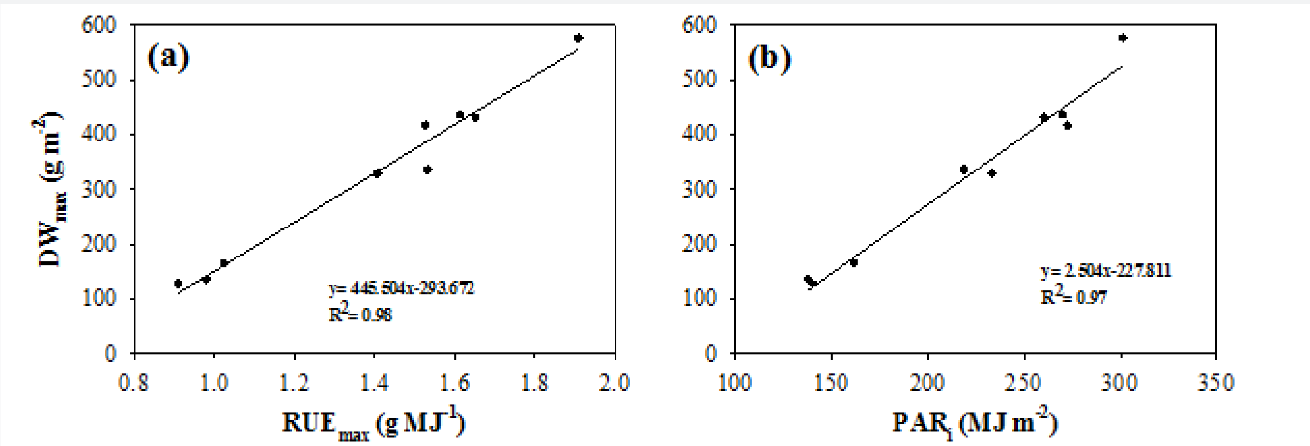

Figure 5: Relationship between (a) maximum dry weight (DW_{max}) and maximum radiation use efficiency (RUE_{max}) of pumkin and (b) maximum dry weight (DW_{max}) and intercepted PAR (PAR_i) of pumpkin for 2010 experiment.

2012 experiment: In 2012 experiment, the effect of three sowing dates (including May 1, May 11 and May 21) and two plant densities (including 2.5 and 4 plant m^{-2}) on pumpkin growth was evaluated. In this experiment, all treatments did not receive any amount of nitrogen fertilizer [74,75]. The analysis of variance showed that sowing date had a highly significant ($P \leq 0.01$) effect on both DW_{max} and RUE_{max} and a significant effect ($P \leq 0.05$) on PAR_i of pumpkin (Table 4). There was no significant difference between two plant densities (including 2.5 and 4 plants m^{-2}) regarding maximum dry weight (DW_{max}) and maximum radiation

How to cite this article: Bannayan M, Mortazagoldani, Mohammad R N.Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes. Agri Res & Tech: Open Access J. 2017; 11(1): 555801. DOI: 10.19080/ARTOAJ.2017.11.555801.

use efficiency (RUE_{max}) of pumpkin (Table 4). However, plant density had a significant effect on intercepted PAR of pumpkin (Table 4). Furthermore, for all three pumpkin traits (including $DW_{ma}x$, RUE_{max} and PAR_i) the effect of sowing date was higher than plant density, i.e. sum of squares obtained for the effect of sowing date on pumpkin traits were higher than those obtained for plant density (Table 4).

Table 4: Analysis of variance for the effect of experimental treatments and their interaction on pumpkin's maximum dry weight (DW_{max}), maximum radiation use efficiency (RUE_{max}) and intercepted PAR (PAR_i) in 2012 experiment.

Source of Variation	Degree of Freedom	Sum of Squares		
		DWmax	RUEmax	PARi
Sowing date (S)	2	22025.01**	0.277**	2593.89*
Plant density (D)	1	129.60NS	0.001NS	1838.20*
S×D	2	62.41NS	0.009NS	454.83NS
Error	6	315.38	0.032	1565.10
CV (%)		3.75	8.95	4.89

*, ** and NS are significant at probability level of 0.05, 0.01 and non-significant, respectively.

The highest amount of pumpkin's DW_{max}, RUE_{max} and PARi was obtained from sowing date of May 1 (Table 5). However, there was no significant difference between sowing dates of May 1 and May 11 regarding all growth parameters of pumpkin (Table 5). Whereas, with delaying the sowing date to May 21, all growth parameters of pumpkin were significantly decreased (Table 5). Therefore, sowing date of 1-11 May can be considered as the optimum sowing date for pumpkin growth under climatic conditions of Mashhad.

Table 5: Effect of sowing date on maximum dry weight (DW_{max}), maximum radiation use efficiency (RUE_{max}) and intercepted PAR (PAR_i) of pumpkin in 2012 experiment.

Sowing date	DW_{max} (g m^{-2})	RUE_{max} (g MJ^{-1})	PAR_i(MJ m^{-2})
May 1	221.00a	0.92a	339.38a
May 11	215.05a	0.89a	337.73a
May 21	144.00b	0.64b	313.13b

Values with the same letter do not have a significant difference according to the LSD test at probability level of 0.05.

For three sowing dates evaluated in 2012 experiment, there was a linear association between maximum dry weight (DW_{max}) of pumpkin and its maximum radiation use efficiency (RUE_{max}) (Figure 6a) and intercepted PAR (PARi) (Figure 6b). Accordingly, the highest amount of pumpkin growth (DW_{max}) obtained from optimum sowing dates (May 1 and May 11) was attributed to their effect on increasing radiation use efficiency (RUE_{max}) and intercepted PAR(PARi) of pumpkin compared to the non-optimum sowing date (May 21) (Table 5). In accordance with the results obtained from this experiment, numerous publications [11,74,75, 76] have reported an increased crop growth and yield with optimum sowing and a reduction in crop growth when sowing is delayed after the optimum time.

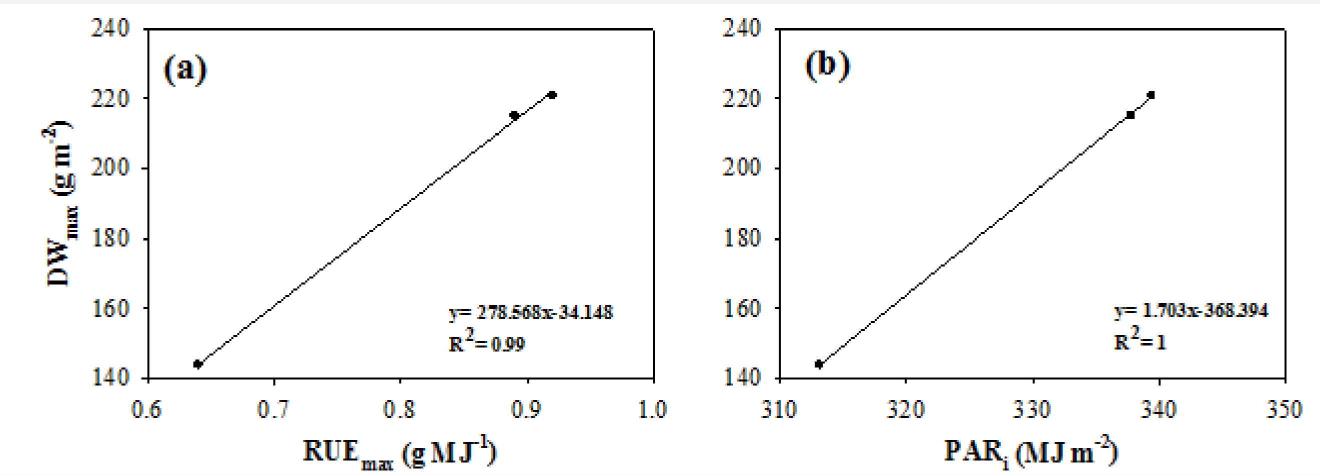

Figure 6: Relationship between (a) maximum dry weight (DW_{max}) and maximum radiation use efficiency (RUE_{max}) of pumkin and (b) maximum dry weight (DW_{max}) and intercepted PAR (PAR_i) of pumpkin for three sowing dates of 2012 experiment.

How to cite this article: Bannayan M, Mortazagoldani, Mohammad R N.Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes. Agri Res & Tech: Open Access J. 2017; 11(1): 555801. DOI: 10.19080/ARTOAJ.2017.11.555801.

For three sowing dates of 2012 experiment, the photo synthetically active radiation (PAR) intercepted by pumpkin had a linear relationship with maximum leaf area index (LAI_{max}) (Figure 7a) and also with maximum leaf area duration (LAD_{max}) (Figure 7a) of this crop [76]. The values of 1.73, 1.63 and 1.05m2 m^{-2} for LAI_{max} and values of 21.2, 19.3 and 13.3m2 day-1 for LAD_{max} were obtained for sowing dates of May 1, May 11 and May 21, respectively. considering the linear association of PARi with LAI_{max} and LAD_{max} (Figure 7) and since the values of LAI_{max} and LAD_{max} for optimum sowing dates (i.e. May 1 and May 11) were higher than those obtained from non-optimum sowing date (i.e. May 21), the higher PAR intercepted by pumpkin grown under optimum sowing date (1-11 May) was related to the increased leaf area index (LAI) and leaf area duration (LAD) (Figure 7).

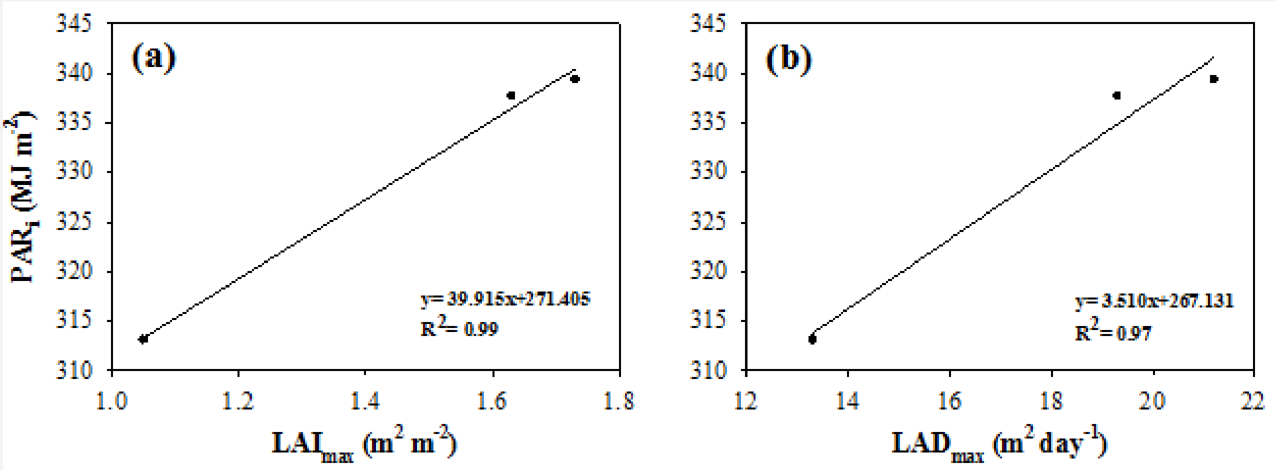

Figure 7: Relationship between (a) intercepted PAR (PAR_i) and maximum leaf area index (LAI_{max}) of pumkin and (b) intercepted PAR (PAR_i) and maximum leaf area duration (LAD_{max}) of pumpkin for three sowing dates of 2012 experiment.

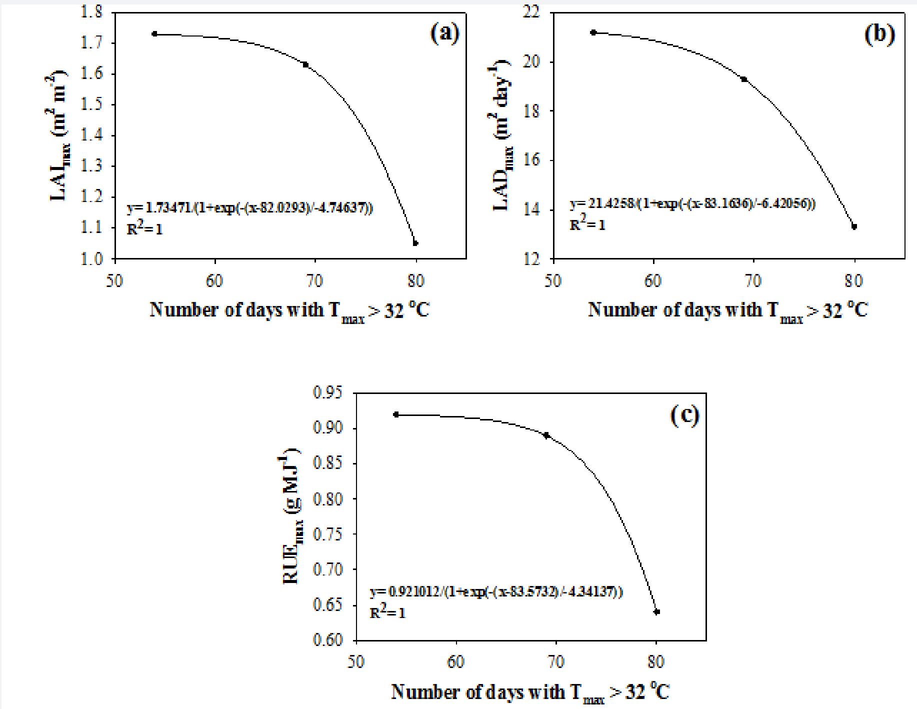

Figure 8: Relationship between (a) maximum leaf area index (LAI_{max}) of pumpkin and number of days with Tmax> 32 °C, (b) maximum leaf area duration (LAD_{max}) of pumpkin and number of days with T_{max}> 32 °C and (c) maximum radiation use efficiency (RUE_{max}) of pumpkin and number of days with T_{max}> 32 oC for three sowing dates of 2012 experiment.

The ceiling temperature for pumpkin growth is 32 °C [77,78] and pumpkin growth is decreased by increasing the number of days with maximum temperature higher than 32 °C (T_{max}> 32 °C). The association between maximum leaf area index (LAI_{max}), maximum leaf area duration (LAD_{max}) and maximum radiation use efficiency (RUEmax) as dependent variables and number of days with T_{max}> 32 °C for three sowing dates of 2012 experiment is showed in Figure 8. These sigmoidal associations (Figure 8)

How to cite this article: Bannayan M, Mortazagoldani, Mohammad R N.Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes. Agri Res & Tech: Open Access J. 2017; 11(1): 555801. DOI: 10.19080/ARTOAJ.2017.11.555801.

indicate that all growth parameters of pumpkin (including LAI_{max}, LAD_{max} and RUE_{max}) were decreased as the number of days with T_{max}> 32 °C increased (Figure 8). The number of days with T_{max}> 32 °C increased by delaying the sowing date, i.e. the number of days with T_{max}> 32 °C for sowing dates of May 1, May 11 and May 21 was 54, 69 and 80 days, respectively. However, considering that there was no significant difference between sowing dates of May 1 and May 11 regarding pumpkin growth (Table 5), the optimum number of days with T_{max}> 32 °C for pumpkin was between 54 to 69 days and higher increase of this number can be resulted in significant decrease of pumpkin growth as observed for sowing date of May 21. Therefore, the higher LAI_{max}, LAD_{max} and RUE_{max} observed under optimum sowing date (1-11 May) was dependent on the more suitable temperature conditions, while the lower values of these growth parameters obtained from non-optimum sowing date (May 21) was related to the temperature stress.

These results showed that negative impacts of weather extremes such as high temperatures on crop growth can be decreased by choosing the optimum sowing date. In contrast, delaying sowing date can cause significant differences of environmental conditions during crop growth, usually causing crops to grow with increasing temperatures and diminishing moisture conditions [12,13], which can be resulted in growth suppression of crop. The significant increase (P ≤ 0.05) in PAR intercepted by pumpkin grown under plant density of 4 plants m^{-2} compared to the plant density of 2.5 plants m^{-2} (Table 4) was related to the higher leaf area index and leaf area duration obtained from plant density of 4 plants m^{-2} (Figure 9). However, this increased interception of PAR did not lead to the significant increase in pumpkin dry weight due to non-significant difference between two plant densities regarding radiation use efficiency (Table 4). Therefore, considering the results of 2010 experiment which showed that among plant densities of 0.625, 1.25 and 2.5 plants m^{-2}, the highest growth of pumpkin was obtained using plant density of 2.5 plants m^{-2} and also in light of the results of 2012 experiment which indicated a non-significant difference between plant densities of 2.5 and 4 plants m^{-2} regarding pumpkin growth, the plant density of 2.5 plants m^{-2} can be considered as the optimum plant density for pumpkin growth.

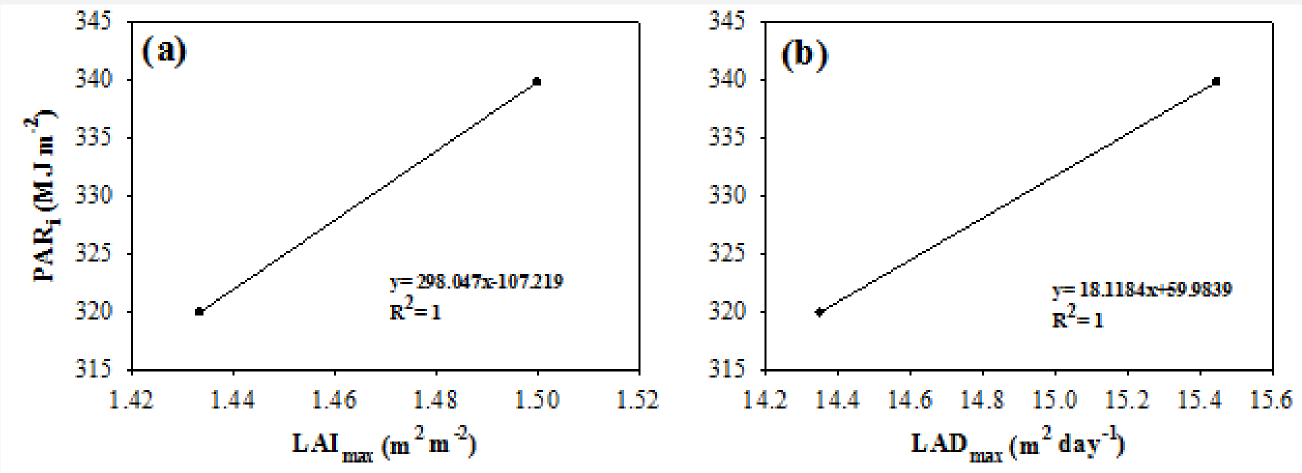

Figure 9: Relationship between (a) intercepted PAR (PAR_i) and maximum leaf area index (LAI_{max}) of pumpkin and (b) intercepted PAR (PAR_i) and maximum leaf area duration (LAD_{max}) of pumpkin for plant densities of 2.5 and 4 plants m-2 in 2012 experiment.

2013 and 2014 experiments: The combined analysis of variance for 2013 and 2014 experiments showed that year had only a highly significant effect (P≤0.01) on maximum dry weight of pumpkin (DW_{max}) (Table 6), while effect of nitrogen rate for all growth parameters of pumpkin (including DW_{max}, RUE_{max} and PARi) was significant at probability level of 0.01 (Table 6). Furthermore, the effect of interaction between year and nitrogen rate (Y × N) was not significant for all growth parameters of pumpkin (Table 6). The higher sum of squares obtained for the effect of nitrogen rate on maximum dry weight of pumpkin (DW_{max}) (Table 6) indicates that impact of nitrogen rate on pumpkin growth was more than the influence of year. In addition, the non-significant difference between two years (2013 and 2014) regarding maximum radiation use efficiency (RUE_{max}) of pumpkin (Table 6) shows that radiation use efficiency of pumpkin is approximately stable across the years and thus, can effectively be used for simulation its dry weight through multiplying by intercepted PAR. Similarly, Sinclair & Muchow [79] reported that RUE is stable across environments.

Table 6: Analysis of variance for the effect of year, nitrogen rate and their interaction on pumpkin's maximum dry weight (DW_{max}), maximum radiation use efficiency (RUE_{max}) and intercepted PAR (PAR_i) in 2013 and 2014 experiments.

Source of Variation	Degree of Freedom	Sum of Squares		
		DW_{max}	RUE_{max}	PAR_i
Year (Y)	1	9126.00**	0.00NS	1443.36NS

How to cite this article: Bannayan M, Mortazagoldani, Mohammad R N.Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes. Agri Res & Tech: Open Access J. 2017; 11(1): 555801. DOI: 10.19080/ARTOAJ.2017.11.555801.

Nitrogen rate (N)	2	362489.33**	0.78**	68040.42**
Y × N	2	172.00NS	0.00NS	87.23NS
Error	12	7461.33	0.20	3598.58
CV (%)		5.07	7.24	5.47

Effect of year on maximum dry weight of pumpkin (DW_{max}) showed that DW_{max} obtained in 2014 year was significantly higher than that obtained in 2013 (Table 7). This was due to a more suitable temperature conditions observed at 2014 growing season which is described in next section. Nitrogen rate had a linear effect on all growth parameters of pumpkin and all of them linearly increased as the nitrogen rate increased (Figure 10). The highest amount of DW_{max}, RUE_{max} and PARi which was obtained from application of 250kg N ha-1 was 641g m^{-2}, 2gMJ-1 and 375MJ m-2, respectively (Figure 10). Since there was a positive strong correlation between DW_{max} with RUE_{max} and PARi of pumpkin (i.e. R2= 0.98 for DW_{max} vs. RUE_{max} and R2= 0.99 for DW_{max} vs. PARi), the increase in pumpkin growth due to increased nitrogen rate was related to the effect of higher rate of nitrogen on increment of the pumpkin RUE and PARi. N affects production through different mechanisms. Increases in crop growth are largely produced through an increase in leaf area index [80,81], intercepted photo synthetically active radiation [16] and also by an increase in radiation use efficiency (RUE, dry matter produced per unit of either incident radiation or intercepted radiation) [80,81

Table 7: Effect of year on maximum dry weight (DW_{max}) of pumpkin.

Year	DW_{max} (g m^{-2})
2013	511.33a
2014	472.33b

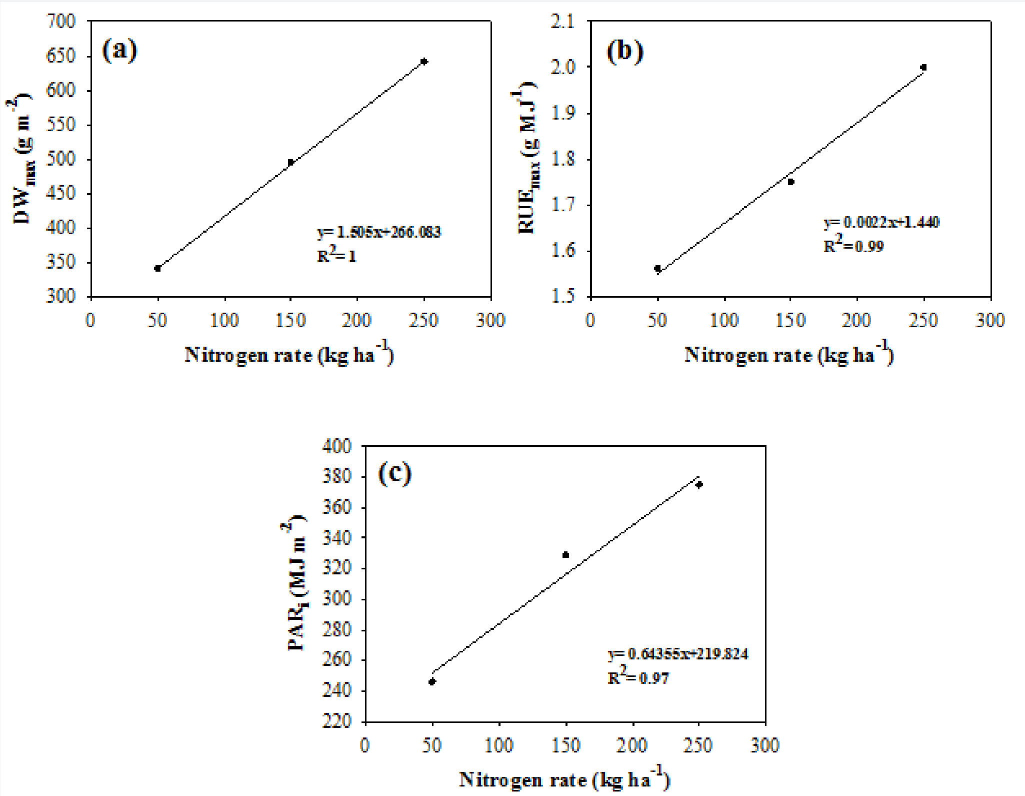

Figure 10: Effect of nitrogen rate on (a) maximum dry weight (DW_{max}) of pumpkin (b) maximum radiation use efficiency (RUE_{max}) of pumpkin and (c) intercepted PAR (PAR_i) of pumpkin across 2013 and 2014 experiments.

Finally, from results of 2010, 2013 and 2014 experiments, it was showed that highest pumpkin growth is obtained through application of 250kgNha^{-1}. Furthermore, results of 2010 and 2012 experiments showed that optimum plant density for pumpkin growth was 2.5 plantm^{-2}, and in 2012 experiment it was indicated that sowing date of 1-11 May was the optimum sowing date for pumpkin growth. Therefore, it can be concluded that optimum conditions for pumpkin growth was: sowing date between 1-11 May, plant density of 2.5 plant m^{-2} and nitrogen rate of 250kgha^{-1}. Among all treatments evaluated in this study only three treatments (including T6-2010, T3-2013 and T3-2014) had the optimum growth conditions (Table 1).

Effect of air temperature

Temperature is the most important climate variable during pumpkin growth life [82], which shows a strong relationship with leaf emergence and number of this crop [83]. Moreover,

How to cite this article: Bannayan M, Mortazagoldani, Mohammad R N.Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes. Agri Res & Tech: Open Access J. 2017; 11(1): 555801. DOI: 10.19080/ARTOAJ.2017.11.555801.

flowering and pollination stages, and duration of development of pumpkin also are very sensitive to air temperature [83]. There is no specific definition and established phenological scale for pumpkin. However, in temperate climates, semi-determinate Cucurbita plants can reach the end of their exponential growth phase within 6 to 7 weeks after sowing [42]. Hence, for evaluating the effect of air temperature on shoot dry weight (DW) of pumpkin, the growth cycle of this crop was divided into three phases based on the growth pattern obtained from experimental data. These growth phases included exponential phase, linear phase and senescent phase.

In 2012 experiment which three sowing dates were employed, the duration of exponential and linear growth phases of pumpkin was linearly decreased (Figure 11a & 11b), while the duration of senescent phase was linearly increased (Figure 11c) as the sowing date moved forward (i.e. air temperature increased). Some processes, e.g. photosynthesis, show continuous and mainly nonlinear changes in their rates if temperature changes. Other processes, such as phonological development, show a much more linear change with variation in temperature [84]. For sowing dates of May 1, May 11 and May 21 (with mean temperature of 25.4, 26.3 and 27.1 °C, respectively) the duration of 42, 40 and 36 days for exponential phase, 31, 30 and 29 days for linear phase and 16, 22 and 30 days for senescent phase. In fact, the duration of all phases of pumpkin growth was decreased with increasing the air temperature (Figure 11) and air temperature during exponential and linear phase for sowing dates of May 1 and May 11 was higher than sowing date of May 21, while during senescent phase, sowing date of May 1 had the highest air temperature (Figure 11). Accordingly, in sowing dates of May 1, May 11 and May 21, the air temperature of 22.6, 24.3 and 25.2 °C for exponential phase, 27.6, 28.0 and 29.0°C for linear phase and 28.7, 27.7 and 27.1 °C for senescent phase was obtained (Figure 11). Since the shoot dry weight of pumpkin in sowing dates of May 1 and May 11 was significantly higher than dry weight obtained in sowing date of May 21, it seems that decrease in duration of exponential and linear phase can be resulted in reduction of pumpkin growth.

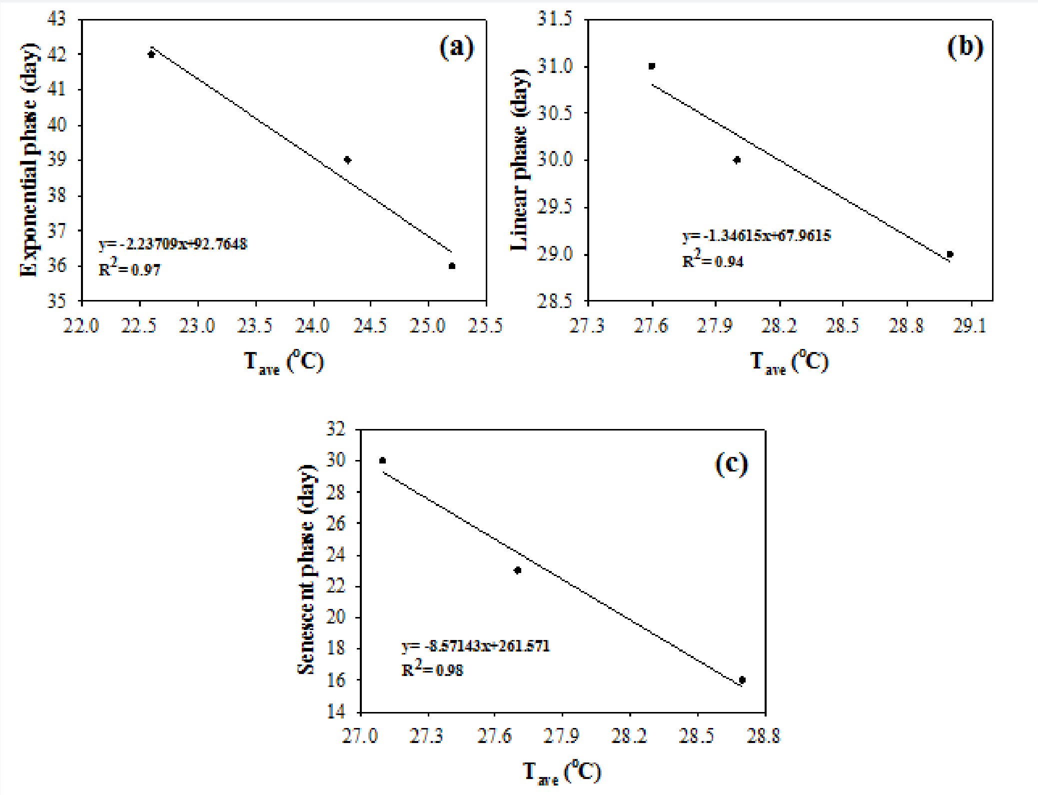

Figure 11: Effect of average of daily mean temperature (T_{ave}) on duration of (a) exponential phase, (b) linear phase and (c) senescent phase of pumpkin growth cycle for three sowing dates of 2012 experiment.

For 2012 experiment, the dry weight of pumpkin in both exponential and linear phase was decreased with increasing the air temperature (Figure 12). However, there was no significant difference between pumpkin dry weight obtained from sowing dates of May 1 and May 11 at both phase. Therefore, in this experiment, the highest dry weight of pumpkin wasobtained at temperatures between 22.6-24.3 °C for exponential phase and 27.6-28 °C for linear phase (Figure 12). Bannayan et al. [78] reported that Rapid vegetative growth of pumpkin requires 22-27 °C thermal environment. Whereas by delaying the sowing date to May 21 or by increasing the air temperature to 25.2 °C for exponential phase and 29.0 °C for linear phase, pumpkin dry weight was significantly decreased in both phase (Figure 12). As previously showed (Figure 8), this significant growth reduction

How to cite this article: Bannayan M, Mortazagoldani, Mohammad R N.Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes. Agri Res & Tech: Open Access J. 2017; 11(1): 555801. DOI: 10.19080/ARTOAJ.2017.11.555801.

was due to temperature stress. However, in senescent phase there was a positive relationship between air temperature and pumpkin dry weight (Figure 12). This positive relationship was related to the higher dry weight produced in previous phases (i.e. exponential and linear) of optimum sowing date (1-11 May). Therefore, earlier planting of pumpkin in Mashhad can be resulted in higher pumpkin growth due to a cooler temperature during exponential and linear phases of its growth cycle. Bannayan et al. [78] studied climatic suitability of pumpkin in different regions of Iran. They reported that Azerbaijan region which had a cooler temperature during flowering and pollination period of growth cycle indicated more favorable climatic suitability for cultivation of pumpkin than other regions. In conclusion, results of 2012 experiment showed that intra-annual temperature variations which are resulted from different sowing dates can be led to the variation in pumpkin growth and by adopting the optimum sowing date, the various growth stages of this crop are coincided with the optimum temperature and this causes to obtaining higher crop growth in comparison with non-optimum sowing dates. Therefore, one of the promising methods for mitigating the impact of global warming on crop growth is the re-establishment of sowing date in order to coinciding growth phases of crop with their optimum temperature. Similarly, Delgado et al. [14] reported that changing the planting date can be considered as an adaptation response to climate change. Matching crop development to the available soil moisture supply, as well as avoiding other environmental constraints such as cool or hot temperatures [85], is a key determinant of adaptation today and will continue to be important in future climates [86].

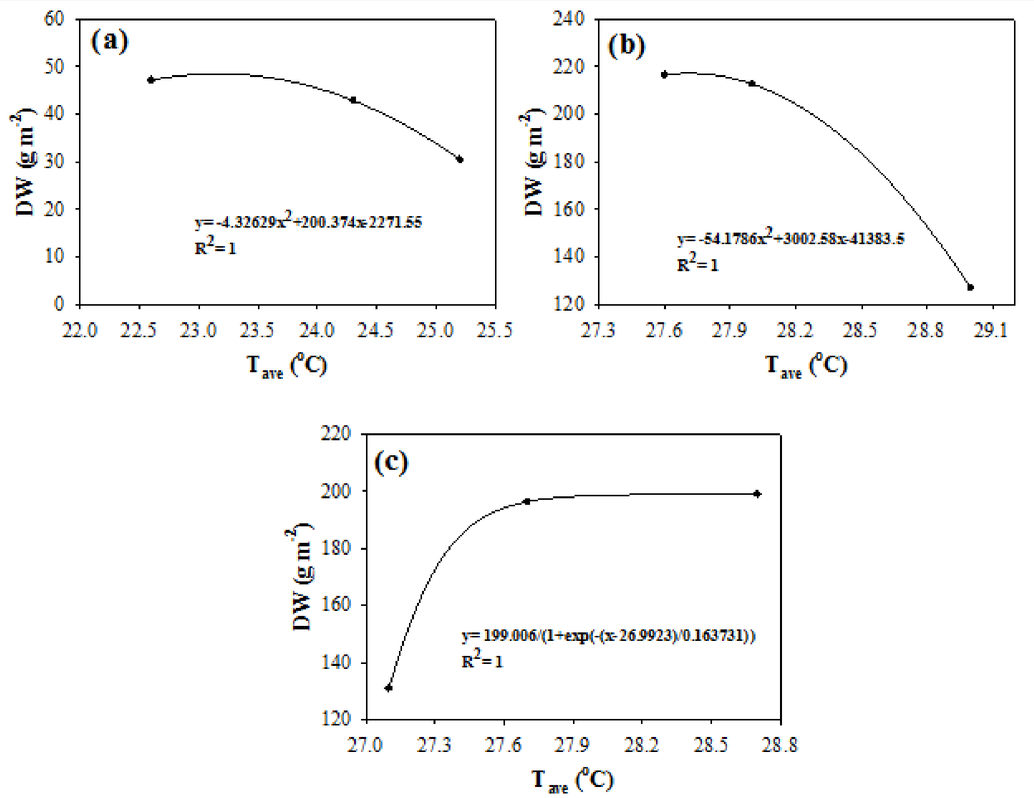

Figure 12: Effect of average of daily mean temperature (T_{ave}) on (a) pumpkin dry weight (DW) in exponential phase, (b) pumpkin dry weight (DW) in linear phase and (c) pumpkin dry weight (DW) in senescent phase for three sowing dates of 2012 experiment.

The effect of air temperature on shoot dry weight of three treatments with optimum growth conditions (i.e. treatments with sowing date between 1-11 May, plant density of 2.5 plants m^{-2} and nitrogen rate of 250kgha-1) also was evaluated. These treatments were included T6-2010, T3-2013 and T3-2014 which were belonged to the 2010, 2013 and 2014 experiments, respectively (Table 1). In exponential phase, pumpkin dry weight (DW) were increased as the air temperature increased and highest DW in this phase was obtained from 2014 year which had the maximum air temperature (i.e. 24 °C) in comparison with two other treatments (Figure 13a). Furthermore, the shoot dry weight of pumpkin in exponential phase of 2013 experiment was higher than 2010, which this was due to higher temperature during exponential phase of 2013 growing season compared to 2010, i.e. 23.5 °C for 2013 vs. 22.8 °C for 2010 (Figure 13a). However, these results were in contrast to 2012 experiment which showed that in exponential phase, pumpkin dry weight was decreased with increasing air temperature (Figure 12). In contrast to 2012 experiment which all treatments did not receive any amount of nitrogen, the positive relationship between pumpkin dry weight and air temperature observed in exponential phase of three treatments with optimum growth conditions

How to cite this article: Bannayan M, Mortazagoldani, Mohammad R N.Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes. Agri Res & Tech: Open Access J. 2017; 11(1): 555801. DOI: 10.19080/ARTOAJ.2017.11.555801.

may be due to interaction between nitrogen and temperature. N deficiency increases sensitivity of plant photosynthesis to heat stress and nitrogen nutrition plays an important role in the protective adaptation of the crop photosynthesis to higher temperatures [87].

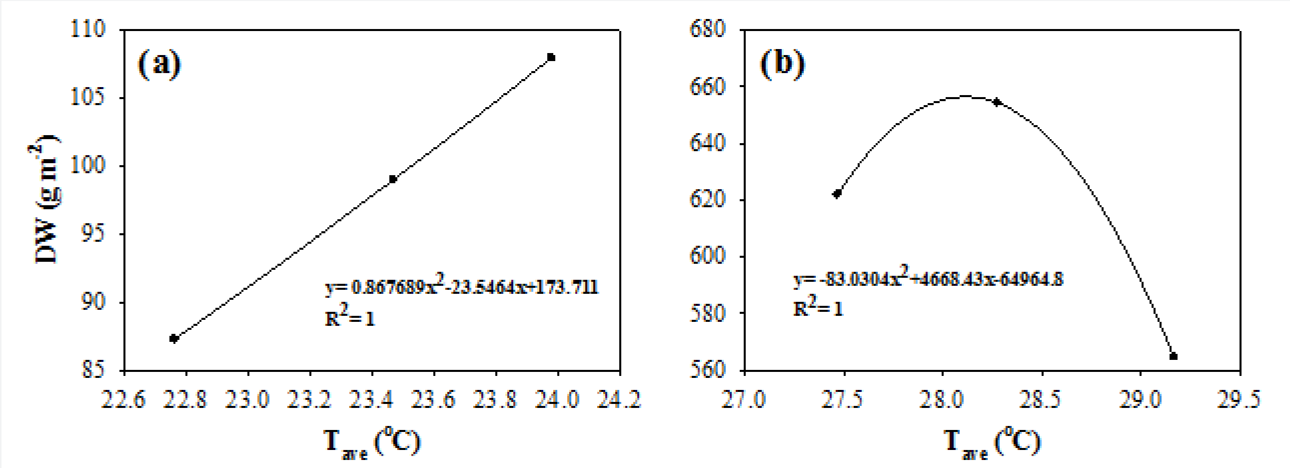

Figure 13: Effect of average of daily mean temperature (T_{ave}) on (a) pumpkin dry weight (DW) in exponential phase and (b) pumpkin dry weight (DW) in linear phase for three treatments with optimum growth conditions (i.e. T6-2010, T3-2013 and T3-2014 treatments).

In linear phase, pumpkin dry weight was increased by increasing air temperature from 27.5 oC (i.e. 2013 year) to 28.3 °C (i.e. 2014 year) and with higher increase in air temperature, the pumpkin dry weight was decreased (Figure 13b). Therefore, the highest pumpkin dry weight in this phase was obtained from 2014 experiment which air temperature during its linear phase was 28.3 °C (Figure 13b). Pumpkin dry weight during linear phase of 2013 experiment was also higher than 2010 which this was because of cooler air temperature observed during linear phase of 2013 compared to 2010, i.e. 27.5 °C for 2013 versus 29.2 °C for 2010 (Figure 13b). Therefore, the greater pumpkin dry weight in 2014 growing season compared to 2013 was related to the higher air temperature observed during both exponential and linear phase of 2014 (Figure 13), while higher pumpkin dry weight of 2013 growing season in comparison with 2010 was due to warmer air temperature during exponential phase and cooler temperature during linear phase of 2013 year (Figure 13). In conclusion, these results showed that inter-annual weather variations also can affect pumpkin growth and optimum nitrogen application may increase pumpkin resistance to higher air temperature.

Conclusion

A number of management practices including different sowing dates, plant densities and nitrogen rates were evaluated in four experimental years (2010, 2012, 2013 and 2014) in order to determining the optimum growth conditions of pumpkin. Results showed that in 2010, 2013 and 2014 experiments, highest pumpkin growth was obtained using application of 250kgNha-1. In 2010 experiment, maximum growth of pumpkin produced under plant density of 2.5 plants m^{-2} and in 2012, there was no significant difference between plant densities of 2.5 and 4 plants m^{-2} regarding pumpkin growth. Furthermore, the significant difference did not observe between pumpkin dry weight obtained from sowing dates of May 1 and May 11 in 2012 experiment. Therefore, according to these results, it was concluded that optimum growth conditions for pumpkin regarding sowing date, plant density and nitrogen rate is 1-11 May, 2.5 plants m^{-2} and 250kg ha^{-1}, respectively. Results also showed that delaying the sowing date to late May can be resulted in significant reduction of pumpkin growth due to temperature stress. Thus, by selecting the optimum planting date, it is possible to mitigate the negative impacts of temperature stress pumpkin on crop growth. Furthermore, fluctuations of air temperature which was related to different sowing dates and different experimental years caused to the variation in pumpkin growth. For three sowing dates of 2012 experiment, pumpkin dry weight was decreased with increasing the air temperature in both exponential and linear phases of pumpkin growth cycle, while for treatments with optimum growth conditions in 2010, 2013 and 2014 years (i.e. T6-2010, T3-2013 and T3-2014 treatments), pumpkin dry weight (DW) in exponential phase was consistently increased as the air temperature increased and in linear phase, pumpkin DW increased to the temperature of 28.3 °C and thereafter dry weight decreased. Since in 2012 experiment no amount of nitrogen was applied, the higher temperature resistance of pumpkin grown under T6-2010, T3-2013 and T3-2014 treatments compared to the 2012 experiment was probably due to applying the optimum rate of nitrogen in these treatments. Therefore, optimum nitrogen rate not only can increase crop growth but also can enhance its resistance to the higher temperatures.

References

1. Juan DJA, Tarjuelo JM, Valiente M, Garcia P (1996) Model for optimal cropping patterns within the farm based on crop water production functions and irrigation uniformity I: Development of a decision model. Agricultural and Water Management 31(1-2): 115-143.

How to cite this article: Bannayan M, Mortazagoldani, Mohammad R N.Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes. Agri Res & Tech: Open Access J. 2017; 11(1): 555801. DOI: 10.19080/ARTOAJ.2017.11.555801.

2. Ko J, Ahuja L, Kimball B, Anapalli S, Ma L, et al. (2010) Simulation of free air CO_2 enriched wheat growth and interactions with water, nitrogen, and temperature. Agricultural and Forest Meteorology 150: 1331-1346.
3. Aggarwal PK (2003) Impact of climate change on Indian agriculture. Journal of Plant Biology 3: 189-198.
4. Aggarwal PK, Kalra N, Chander S, Pathak H (2006) Info Crop: A dynamic simulation model for the assessment of crop yields, losses due to pests, and environmental impact of agro-ecosystems in tropical environments. I. Model description. Agricultural Systems 89: 1-25.
5. Lehmann N, Finger R, Klein T, Calanca P, Walter A (2013) Adapting crop management practices to climate change: Modeling optimal solutions at the field scale. Agricultural Systems 117: 55-65.
6. Gayler S, Wang E, Priesack E, Schaaf T, Maidl FX (2002) Modeling biomass growth, N-uptake and phenological development of potato crop. Geoderma 105: 367-383.
7. Lobell DB, Burke MB, Tebaldi C, Mastrandrea MD, Falcon WP, et al. (2008) Prioritizing climate change adaptation needs for food security in 2030. Science 319: 607-610.
8. McLeod JG, Campbell CA, Dyck FB, Vera CL (1992) Optimum seeding dates of winter wheat in southwestern Saskatchewan. Agronomy Journal 84(1): 86-90.
9. Ferrise R, Triossi A, Stratonovitch P, Bindi M, Martre P (2010) Sowing date and nitrogen fertilisation effects on dry matter and nitrogen dynamics for durum wheat: An experimental and simulation study. Field Crops Research 117: 245-257.
10. Anderson WK, Smith WR (1990) Yield advantage of two semi-dwarf compared with two tall wheats depends on sowing time. Agricultural and Forest Meteorology 41: 811-826.
11. Bassu S, Asseng A, Motzo R, Giunta F (2009) Optimizing sowing date of durum wheat in a variable Mediterranean environment. Field Crops Research 111: 109-118.
12. Panozzo JF, Eagles HA (1999) Rate and duration of grain filling and grain nitrogen accumulation of wheat cultivars grown in different environments. Agricultural and Forest Meteorology 50(6): 1007-1016.
13. Subedi KD, Ma BL, Xue AG (2007) Planting date and nitrogen effects on grain yield and protein content of spring wheat. Crop Science 47(1): 36-44.
14. Delgado JA, Nearing MA, Rice CW (2013) Conservation Practices for Climate Change Adaptation. Advances in Agronomy 121: 47-115.
15. Weinhold BJ, Todd PT, Reichman GA (1995) Yield and nitrogen efficiency on irrigated corn in northern Great Plans. Agronomy Journal 87: 842-846.
16. Razzaghi F, Plauborg F, Jacobsen S, Jensen CR, Andersen MN (2012) Effect of nitrogen and water availability of three soil types on yield, radiation use efficiency and evapo transpiration in field-grown quinoa. Agricultural Water Management 109: 20-29.
17. Di QL, Qi-yuan T, Yun-bo Z, Jian-quan Q, Hu L, et al. (2012) Effect of nitrogen regimes on grain yield, nitrogen utilization, radiation use efficiency, and sheath blight disease intensity in super hybrid rice. Journal of Integrative Agriculture 11: 134-143.
18. Aulakh MS, Malhi SS (2005) Interactions of nitrogen with other nutrients and water: effect on crop yield and quality, nutrient use efficiency, carbon sequestration, and environmental pollution. Advances in Agronomy 86: 341-409.
19. Bridge RR, Meredith WR, Chism JF (1973) Influence of planting method and plant population on cotton (Gossypiumhirsutum). Agronomy Journal 65(1): 104-109.
20. Shinnawy EA, Ghaly FM (1985) Effect of plant density on growth and yield in two Upland cotton cultivars (G. hirsutum L.). Agricultural Research Review Egyptian 63: 109-119.
21. Halemani HL, Hallikeri SS (2002) Response of compact and early maturing cotton genotypes to plant population levels under rainfed conditions. Journal Cotton Research and Development 16: 143-146.
22. Jing Q, Bouman B, Keulen VH, Hengsdijk H, Cao W, et al. (2008) Disentangling the effect of environmental factors on yield and nitrogen uptake of irrigated rice in Asia. Agricultural Systems 98: 177-188.
23. Hoogenboom G (2000) Contribution of agrometeorology to the simulation of crop production and its applications. Agricultural and Forest Meteorology 103: 137-157.
24. Decker WL (1994) Developments in agricultural meteorology as a guide to its potential for the twenty-first century. Agricultural and Forest Meteorology 69: 9-25.
25. Bannayan M, Eyshi RE, Alizadeh A (2011) Climatic Suitability of Growing Summer Squash (Cucurbita pepo L.) as a Medicinal Plant in Iran. Notulae Scientia Biologicae 3(2): 39-46.
26. Alexandrov VA, Hogenboom G (2000) The impact of climate variability and change on crop yield in Bulgaria. Agricultural and Forest Meteorology 104: 315-327.
27. Bannayan M, Hoogenboom G (2008) Weather analogue: A tool for real-time prediction of daily weather data realizations based on a modified k-nearest neighbor approach. Environmental Modeling and Softwares 23: 703-713.
28. Hodges T (1998) Water and nitrogen applications for potato: commercial and experimental rates compared to a simulation model. Journal of Sustainable Agriculture 13: 79-90.
29. Wilson DR, Muchow RC, Murgatroyd CJ (1995) Model analysis of temperature and solar radiation limitations to maize potential productivity in a cool climate. Field Crops Research 43: 1-18.
30. Tao F, Yokozawa M, Zhang, Z (2009) Modelling the impacts of weather and climate variability on crop productivity over a large area: A new process-based model development, optimization, and uncertainties analysis. Agricultural and Forest Meteorology 149: 831-850.
31. Monteith JL (1977) Climate and the efficiency of crop production in Britain. Philosophical Transaction of the Royal Society of London 281: 277-294.
32. Chen YH, Yu SL, Yu ZW (2003) Relationship between amount or distribution of PAR interception and grain output of wheat communities. Acta Agronomica Sinica 29(5): 730-734.
33. Li DQ, Tang QY, Zhang YB, Qin JQ, Li H, et al. (2012) Effect of nitrogen regimes on grain yield, nitrogen utilization, radiation use efficiency, and sheath blight disease intensity in super hybrid Rice. Journal of Integrative Agriculture 11: 134-143.
34. Shen XY, Dai JY, Hu AC, Gu WL, Zheng B (1993) Studies on relationship among character of canopy light interception and yield in maize populations (Zea mays L.). Actaagronomicasinica 19: 246-252.
35. Whimeld DM, Smith CJ (1989) Effect of irrigation and nitrogen on growth, light interception and efficiency of light conversion in wheat. Field Crops Research 20: 279-295.
36. Mayers JD, Lawn RJ, Byth DE (1991) Agronomic studies on soybean [Glycine max (L.) Merrill] in the dry Season of the tropics. I. Limits to yield imposed by phenology. Agricultural and Forest Meteorology 42(7): 1075-1092.
37. Marcelis LFM, Heuvelink E, Goudriaan J (1998) Modelling biomass production and yield of horticultural crops: a review. Scientia Horticulturae 74: 83-111.

How to cite this article: Bannayan M, Mortazagoldani, Mohammad R N.Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes. Agri Res & Tech: Open Access J. 2017; 11(1): 555801. DOI: 10.19080/ARTOAJ.2017.11.555801.

38. Pardossi A, Giacomet P, Malorgio F, Albini FM, Murelli C, et al. (2000) The influence of growing season on fruit yield and quality of greenhouse melon (*Cucumismelo L.*) grown in nutrient film technique in a Mediterranean climate. The Journal of Horticultural Science and Biotechnology 75(4): 488-493.

39. Fu C, Shi H, Li Q (2006) A review on pharmacological activities and utilization technologies of pumpkin. Plant Food for Human Nutrition 61(2): 70-77.

40. Tamer CE, Incedayi B, Parseker AS, Yonak S, Copur OU (2010) Evaluation of several quality criteria of low calorie pumpkin dessert. Notulae Botanicae Horti Agro botanici Cluj-Napoca 38(1): 76-80.

41. Kostalova Z, Hromadkova Z, Ebringerova A (2009) Chemical evaluation of seeded fruit biomass of oil pumpkin (Cucurbita pepo L. var. styriaca). Chemical Papers 63(4): 406-413.

42. Brent LJ (2004) Morpho-Physiological Aspects of Productivity and Quality in Squash and Pumpkins (Cucurbita spp.). Critical Reviews in Plant Science 23: 337-363.

43. Bannayan M, Sanjani S (2011) Weather conditions associated with irrigated crops in an arid and semi-arid Environment. Agricultural and Forest Meteorology 151: 1589-1598.

44. Rouphael Y, Colla, G (2005) Radiation and water use efficiencies of greenhouse zucchini squash in relation to different climate parameters. European Journal of Agronomy 23: 183-194.

45. Pohlert T (2004) Use of empirical global radiation models for maize growth simulation. Agricultural and Forest Meteorology 126: 47-58.

46. Ameri AA, Nassiri Mahallati M (2009) Effects of nitrogen application and plant densities on flower yield, essential oils, and radiation use efficiency of Marigold (*Calendula officinalis L.*). Pajouhesh and Sazandegi 81: 133-144.

47. Maddonni GA, Otegui ME (1996) Leaf area, light interception, and crop development in maize. Field Crops Research 48: 81-87.

48. Jongschaap REE (2007) Sensitivity of a crop growth simulation model to variation in LAI and canopy nitrogen used for run-time calibration. Ecological modeling 200: 89-98.

49. Marcelis LFM, Heuvelink E, Goudriaan J (1998) Modelling biomass production and yield of horticultural crops: a review. Scientia Horticulturae 74: 83-111.

50. McMaster GS, Wilhelm WW (1997) Growing degree-days: one equation, two interpretations. Agricultural and Forest Meteorology 87: 291-300.

51. Shabahang J, Khoramdel S, Asadi G, Mirabi E, Nemati H (2010) Effect of intra and inter row space and planting arrangement on yield components and seed and oil yield of pumpkin (*C. pepo L.*). Iranian Journal of Agroecology 2: 417-427.

52. Vos J, vander PEL (2005) Effect of nitrogen supply on leaf growth, leaf nitrogen economy and photosynthetic capacity in maize. Field Crops Research 93: 64-73.

53. Li S, Wheeler T, Challinor A, Lin E, Ju H, et al. (2010) The observed relationships between wheat and climate in China. Agricultural and Forest Meteorology 150: 1412-1419.

54. Muchow RC, Davis R (1988) Effect of nitrogen supply on the comparative productivity of maize and sorghum in a semiarid tropical environment. II- Radiation interception and biomass accumulation. Field Crops Research 18: 17-30.

55. Dewikat IM, Kostewicz SR (1989) Row arrangement, plant spacing, and nitrogen rate effects on zucchini squash yield. Horticultural Science 24(1): 86-88.

56. Gholipoori A, Javanshir A, Rahim ZF, Mohammadi A, Biat H (2007) The effect of different nitrogen level and pruning of head on yield and yield components of medicinal pumpkin (*C. pepo L.*). Iranian Journal of Agricultural Sciences and Natural Resources 13: 1-9.

57. Swaider JM, Moor A (2002) SPAD-chlorophyll response to nitrogen fertilization. Journal of Plant Nutrition 25(5): 1089-1100.

58. Wei DH, Zhou PS, Tian LL, Hong ZY, Hua Z (2014) Nitrogen Nutrition Index and Its Relationship with N Use Efficiency, Tuber Yield, Radiation Use Efficiency, and Leaf Parameters in Potatoes. Journal of Integrative Agriculture 13: 1008-1016.

59. Justes E, Denoroy P, Gabrielle B, Gosse G (2000) Effect of crop nitrogen status and temperature on the radiation use efficiency of winter oilseed rape. European Journal of Agronomy 13: 165-177.

60. Patanè C, Cosentino SL (2013) Yield, water use and radiation use efficiencies of kenaf (*Hibiscus cannabinus L.*) under reduced water and nitrogen soil availability in a semi-arid Mediterranean area. European Journal of Agronomy 46: 53-62.

61. Hall AJ, Connor DJ, Sadras VO (1995) Radiation-use efficiency of sunflower crops: effects of specific leaf nitrogen and ontogeny. Field Crops Research 41: 65-77.

62. Fletcher AL, Johnstone PR, Chakwizira E, Brown HE (2013) Radiation capture and radiation use efficiency in response to N supplyfor crop species with contrasting canopies. Field Crops Research 150: 126-134.

63. Friedrich JW, Schrader LE (1978) Sulphur deprivation and nitrogen metabolism in maize seedlings. Plant Physiology 61(6): 900-903.

64. Stewart BA, Porter LK (1969) Nitrogen-sulphur relationships in wheat (*Triticumaestivum L.*), corn (Zea mays) and beans (*Phaseolus vulgaris*). Agronomy Journal 61(2): 267-271.

65. Monteith JL (1972) Solar radiation and productivity in tropical ecosystems. The Journal of Applied Ecology 9: 747-766.

66. Mao L, Zhang L, Zhao X, Liu S, Zhang S, et al. (2014) Crop growth, light utilization and yield of relay intercropped cotton as affected by plant density and a plant growth regulator. Field Crops Research 155: 67-76.

67. Cao W, White JW, Wang E (2009) Crop Modeling and Decision Support. Tsinghua University Press, Beijing and Springer Verlag Berlin Heidelberg.

68. Ebadi A, Gholipoori AGH, Nikkhah BR (2008) Effect of head pruning and between row spacing on yield and yield components of pumpkin (*Cucurbita pepo L.*). Pajouhesh & Sazandegi 78: 41-47.

69. Douglas JA, Dyson CB, Hacking NJA (1990) Effect of plant population and spatial arrangement on yield and fruit size of buttercup squash. New Zealand Journal Crop and Horticultural Science 18: 99-103.

70. Buwalda JG, Freeman RE (1986) Growth and development of hybrid squash (Cucurbita maxima L.) in the field. The Agronomy Society of New Zealand 16: 7-11.

71. Broderick CE (1982) Morpho-physiological Factors Affecting Plant Productivity of Winter Squash (Cucurbita maxima Duch.). Ph.D. Dissertation, University of New Hampshire, Durham.

72. Taye M, Lommen WJM, Struik PC (2013) Seasonal light interception, radiation use efficiency, growth and tuber production of the tuber crop Plectranthusedulis. European Journal of Agronomy 45: 153-164.

73. Willey RW (1990) Resource use in intercropping systems. Agricultural Water Management 17(1-3): 215-231.

74. Connor DJ, Theiveyanathan S, Rimmington GM (1992) Development, growth, water-use and yield of a spring and a winter wheat in response to time of sowing. Agricultural and Forest Meteorology 43(3): 493-516.

75. Owiss T, Pala M, Ryan J (1999) Management alternatives for improved durum wheat production under supplemental irrigation in Syria. European Journal of Agronomy 11: 255-266.

How to cite this article: Bannayan M, Mortazagoldani, Mohammad R N.Growth Analysis of Pumpkin (*Cucurbita pepo L.*) Under Various Management Practices and Temperature Regimes. Agri Res & Tech: Open Access J. 2017; 11(1): 555801. DOI: 10.19080/ARTOAJ.2017.11.555801.

76. Bannayan M, Eyshi Rezaei E, Hoogenboom G (2013) Determining optimum sowing dates for rainfed wheat using the precipitation uncertainty model and adjusted crop evapotranspiration. Agricultural Water Management 126: 56-63.

77. NeSmith DS (1997) Summer squash (*Cucurbitu pepo L.*) leaf number as influenced by thermal time. Scientia Horticulturae 68: 219-225.

78. Bannayan M, Sadeghi LS, Sanjani S, Mohamadian A, Aghaalikhani M (2010) Effects of precipitation and temperature on crop production variability in northeast Iran. International Journal of Biometeorology 55(3): 387-401.

79. Sinclair TR, Muchow RC (1999) Radiation use efficiency. Adv Agron 65: 215-265.

80. Brown SC, Keatinge JDH, Gregory PJ, Cooper PJM (1987) Effects of fertilizer, variety and location on barley production under rainfed conditions in Northern Syria. I. Root and shoot growth. Field Crops Research 16: 53-66.

81. Lawlor DW (1995) Photosynthesis, productivity and environment. Journal Experimental Botany 46: 1449-1461.

82. Smith DSN (1997) Summer squash (*Cucurbita pepo L.*) leaf number as influenced by thermal time. Scientia Horticulturae 68: 219-255.

83. Whitaker TW, Davis GN (1962) Cucurbits. Inter Sci INC, New York, USA, p. 10.

84. Bussel VLGJ, Müller C, Keulen VH, Ewert F, Leffelaar PA (2011) The effect of temporal aggregation of weather input data on crop growth models' results. Agricultural and Forest Meteorology 151: 607-619.

85. Flower DJ (1996) Physiological and morphological features determining the performance of the sorghum landraces of northern Nigeria. Australian Journal of Experimental Agriculture 32(2): 129-141.

86. Craufurd PQ, Vadez V, Krishna JSV, Vara Prasad PV, Zaman A M (2013) Crop science experiments designed to inform crop modeling. Agricultural and Forest Meteorology 170: 8-18.

87. Lu CM, Zhang JH (2000) Photosystem II photochemistry and its sensitivity to heat stress in maize plants as affected by nitrogen deficiency. Journal of Plant Physiology 157(1): 124-130.

DOI: 10.19080/ARTOAJ.2017.11.555801