Adaptation Strategies in Response to the Effect of Climate Change on Tomato Production

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Abstract: Climate change is one of the largest challenge of this century. Globally, climate change causes drops in yield for their most valuable crops, particularly in developing countries. Afghanistan is one of the world's most vulnerable countries to the negative consequences of climate change. Tomato cultivation is a means of livelihood for most farmers in Afghanistan. The aim of this study was to assess the adaptation strategies on tomato production in response to the impact of climate change in Ghazni province. The study findings indicate a rise in both maximum and minimum temperatures, combined with a decline in annual precipitation over the ten years (2008-2017) period in an unreliable seasonal distribution. The study found that the occurrence of pests and diseases had a substantial impact on tomato production due to climate change. Present study highlights the role of climate variables in the production of tomatoes (temperature and precipitation) while controlling other confounding factors. Selection of crop variety according to climate change and planting time are the two adaptation methods to cope up with the drastic change in the climate to retain the productivity to some extent.

Keywords: Climate change, adaptation strategies, tomato production.

Introduction

The range of distinct climates in Afghanistan has a wide natural variability; however, people are beginning to perceive climatological changes over recent decades (NEPA and UNEP, 2015). Afghanistan is included in the world's most helpless countries with damaging consequences of climate change. The initial national study of the United Nations Framework Convention on Climate Change (UNFCCC) recorded a rise in the country's average annual temperature by 0.6 °C since 1960. The decline in plant growth may be the net consequence of these extreme climatic events, which have a negative effect on the yield of most vegetable crops, especially tomatoes, which are very sensitive to temperatures and variations in rainfall. In tomatoes, water stress associated with temperatures above 28°C caused a 30-45 percent drop in flowers in various cultivars (Bray et al., 2000). Extreme climatic conditions such as floods and droughts have a greater negative impact on tomato production (Bita and Gerats, 2013). Higher temperatures have a negative effect on soil moisture, while prolonged droughts and rising temperatures create favorable conditions for the multiplication of pests and diseases, thereby reducing crop yield (Garrett et al., 2013). Increase in the temperature and changes in the pattern of precipitation have potential to affect crop yields (Reilly et al., 2001). Adaptation may be natural or human induced in response to or impacts of real or anticipated environment stimuli that moderate damage or take advantage of beneficial opportunities (IPCC, 2007). Climate change adaptation can be implemented by modifying systems to tolerate long-term gradual change and by the resilience that consists of modifying systems to allow them to absorb and react to short-term

changes without passing critical threshold limits and moving to alternative equilibrium states (Barnett, 2001). Irrigation management, changes in cropping patterns, change in planting time and implementation of drought-tolerant varieties are adaptation steps in agriculture. Therefore, climate adaptation can be summarized as a collection of actions, strategies, processes and policies that respond to real or anticipated climate change in order to minimize the effects on individuals, communities and the economy (Pinto et al., 2012).

Materials and Methods

The experiment was carried out in Spandeh village of Ghazni province, Afghanistan. It is located at 33.4982° N, 67.7616° E. Its average annual rainfall is 320 mm and the average temperature is 22 °C. The study was conducted in two phases; Phase 1: collected the socioeconomic data from two different resources. Primary data were obtained from main informants such as tomato farmers, provincial agricultural extension officers, while secondary data were obtained from the civil aviation authority's meteorological department and the Ministry of Agriculture, Irrigation and Livestock (MAIL), respectively. A total of 150 individual farmers were randomly selected from ten villages for adaptation strategies in response to the effect of climate change on tomato production, survey interviews, and in-depth interviews used to obtain qualitative responses from key informants. Phase 2: Agronomical study was conducted to evaluate the adaptation strategies in response to the effect of climate change on tomato production. An experiment with randomized complete block design was carried in field. Four tomato varieties (Rio Grande, Dollar, Roma

and Bambino) and two transplanting dates (1st Jun and 15th Jun) were used as main factors, while types of irrigation and mulching were used as sub-factors. When tomato seedling had 4 to 5 true leaves transferred into the field. Mean daily temperature at 1st Jun transplanting date was 16°C, and on 15th Jun transplanting date the mean daily temperature was 18.5°C, respectively.

Data Processing and Analysis

The data for this study were processed and analyzed quantitatively and qualitatively. Using descriptive statistics, the quantitative data were analyzed using the social science software statistical kit and the Microsoft Excel Software. Secondary data (climate and tomato production) were used covering a span of 10 years (2008-2017). The pattern analysis was based on climate data, while the combination of climate and tomato output data were used simultaneously to analyze the impact of climate variability. The trend analysis was based on two variables; temperature and rainfall. To evaluate the nature and direction of the trend of the variables, the trend line, line chart, trend equation and degree of variance within the excel function were used under investigation.

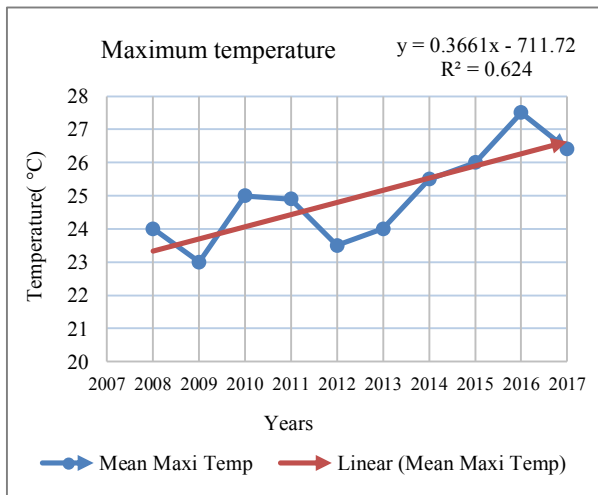**Results and Discussion**

Climate Variables Trends

Fig. 1 Maximum temperature trend in Ghazni province
(Source: AMD, 2020).

It is evident from Figure 1 that the maximum temperature has varied over the ten years (2008-2017) period. The maximum temperature mostly oscillated and increased from 25 °C to 27.5 °C in the study area, particularly in the years (2014-2016). From the time series data, it is evident that the highest maximum temperature of 27.5 °C was recorded in 2016. The trend equation and the mean maximum temperature trend lines indicate a rising trend (0.3661x), which means that over the years (2008-2017) the average maximum temperature has risen. The degree of

variance ($R2=0.62$) represents variability in maximum temperature in the area which is less than one percent. This clearly indicates an increase in the maximum temperature in the study area. According to Hansen et al. (2012) more warming conditions would be experienced in the 21st century than the past decades.
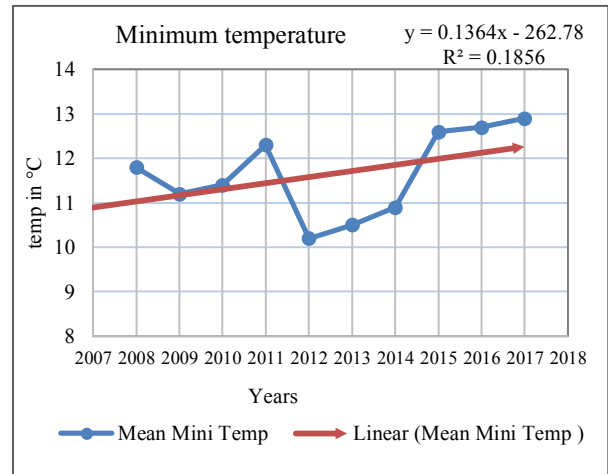

Fig. 1 Minimum temperature trend in Ghazni province
(Source: AMD, 2020).

Figure 2 showed fluctuations in the minimum temperature over the last ten years (2008-2017). The minimum temperature decreased dramatically in the year (2012). Furthermore, it was slightly increased up to 11°C in 2014. Later in 2015, drastic increase in minimum temperature was recorded as 12.7°C. It is evident from the graph presented that after 2015, the minimum temperature in the Ghazni was rising up to 13°C (Fig. 2). The degree of variance ($R2=0.186$) indicates that there is less than 1 percent minimum temperature variability in the area. As the area was experiencing an increase in minimum temperature, it affects directly or indirectly on the growth and yield of plants, particularly tomatoes, in the long run.
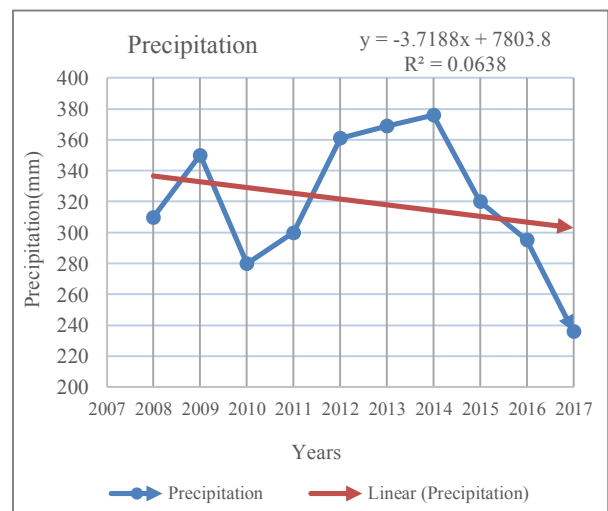

Fig. 2 Annual precipitation trend in Ghazni province.
(Source: AMD, 2020).

A detailed account of the pattern of rainfall variability in the study area is shown in Figure 3. The annual

amount of precipitation shows a declining trend over the last ten years. Initially, an increase in annual rainfall (apx. 350 mm) was recorded in 2009. Then noticeably sharp decline in average rainfall (from 350 mm to 280 mm) was recorded in 2010. However, in later years it was recorded as continuous increase up to 376 mm till 2014. In contrast, drastic decline in average precipitation was observed from 376 to 250 mm in the year 2014 to 2017. The trend equation and the annual rainfall trend line indicate a gradual decreasing (minus) trend (3,7461x), which demonstrates that the average rainfall pattern has decreased at a steady rate over the years (2008-2017). The degree of variance indicates that the variability in the area's annual precipitation is less than 1% (R2 = 0.0495). In general, the total annual precipitation has decreased over the last 10 years as there was a decreasing trend for both rainfall and snowfall in the study area.

Impact of Climatic Variability on Production of Tomato

Change in climate specifically, temperature and rainfall greatly affects the growth and productivity in the area. Relationship in climate change and tomato productivity in Ghazni province are shown (Fig.4, 5) .Climatic variability has been recorded to have its direct as well as indirect effect on the production of tomato in the study area. It is clearly evident that production in this area declined from 2008 to 2017.
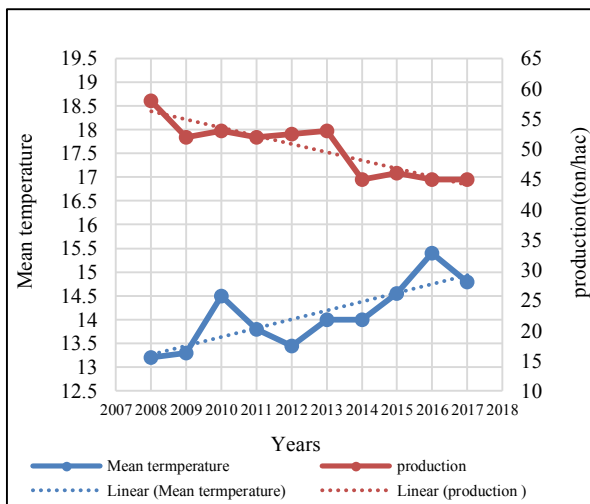

Fig. 4 Production in contrast with temperature.

Data presented in Figure 4 showed, reverse trend in the parameters. With respect to increase in mean temperature the productivity of tomato decreased from 2008 to 2017. Similar findings were reported by Kalibbala (2011) that change in temperature was the main cause in total tomato yield reduction. The amount of annual precipitation also had its effect on tomato production in the study area during the last ten years (2008-2017). With dissembling the effect of other variables it is observed that by declining the precipitation the production also decreases.
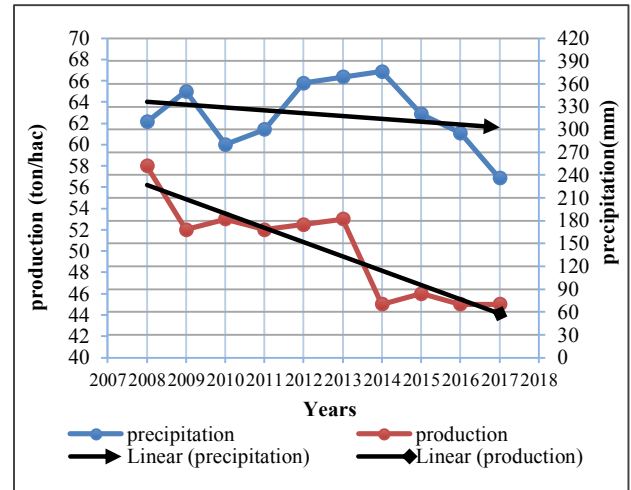

Fig. 5 Production in contrast to precipitation.

Data clearly demonstrate the interaction of precipitation and tomato productivity during ten years (2008-2017) study period (Fig. 5). That the irreversible relationship between precipitation and total tomato production was noticed by trend line in this figure. After 2013, the tomato production declined drastically that could be as a result of other factors in coordination with the temperature in the study area. By disregarding the effects of some confounding variables (i.e. soil type, irrigation, agrochemical application, regular weeding, and varieties of tomatoes etc). Further correlation analysis was done to find the more expressive picture of the data observed in the study period by using SPSS V16.0. The rainfall and temperature data were used to show a correlation between these two variables and tomato production in the study area. On the Pearson's Product – moment correlation results, it is clear that there is relationship between both the mean temperature and production as well as the precipitation and the production in the study area.

Table 1. Relationships between temperature, precipitation and production in Ghazni province (2008-2017).

Correlations		Production	Temperature	precipitation
Production	Pearson Correlation	1.0	-0.513	0.183
	Sig. (2-tailed)		0.130	0.614
	N	10.0	10	10
Temperature	Pearson Correlation	-.513	1	-.121
	Sig. (2-tailed)	NS		.739
	N	10	10	10
precipitation	Pearson Correlation	.183	-.121	1
	Sig. (2-tailed)	NS	.739	
	N	10	10	10

The result of correlation shows that there is a relatively large negative relationship between the temperature and the production of (r = -0.513) in the study area. It

means that by increasing the annual temperature in ten years of (2008 – 2017) the production of tomato in Ghazni province has been decreased. From the Pearson's product moment correlation table, it showed a positive correlation between precipitation and the area of production in the study area. The value of the correlation is positive and near the zero (0.183). This means that the impact of precipitation on tomato production in the area was less effective as compared to change in temperature.

Strategies for adaptation in response to the effects of climate change

Table 2. Farmers adaptation strategies in response to the impact of climate change.

Farmers' adaptation strategies	Ghazni Province			
	Yes n (%)		Yes n (%)	
Farmers' adaptation strategies	147	(98)	3	(2)
	138	(92)	12	(8)
Changes in crop variety	114	(76)	36	(24)
Adjusting cropping Season	59	(39.3)	91	(60.7)
Irrigation	145	(96.6)	5	(3.4)

Tomato farmers in the study area use various on-farm strategies to adapt to climate change (Table 2). The majority of farmers 147 (98 %) changed the variety of tomatoes (such as Rio Grande, Bambino and Roma) as an adaptive measure. Only 3 (2%) answered negatively, indicating their resolve not to change the variety of tomatoes. The secret to sustaining yield stability would be the production of new crop varieties with greater yield potential and tolerance to multiple stresses flood, drought, and salinit) (Lobell et al., 2008). Adjusting cropping season as an adaptive strategy was preferred by the farmers in the event of climate change affecting tomatoes. While 138 (92%) of the farmers adjust with cropping season. Only 12 (8%) answered negative, indicating their resolve not to adjusting cropping season. Irrigation as an adaptive strategy was also found to be an adaptive measure. It was observed that 114 (76%) employed drip irrigation as a strategy to eradicate tomato diseases. This result agrees with the findings of Kato et al. (2011), who noted that technologies for water-saving and conservation serve as a buffer against the risk of production in the context of climate change as well as its variability. The application of agro-chemicals as an adaptive strategy was found to be an adaptive measure to improve the fertility of the soil and eradicate tomato diseases. Mulching was also found to be and adaptive measure. Generally it was observed that 145 (96.6%) employed organic mulching as a strategy to conserve soil moisture.

The result of the experiment (table.3) showed non-significant production of various tomato varieties (Table 3).

Table 3. Interaction effects of different varieties and planting dates on number of flowers, fruit setting, yield per plant and yield.

Treatments	Planting time	Number of flowers	Fruit setting (%)	Yield/plant (kg)	Yield (T/ha)
Rio Grande	1	160.7	70.3	3.2	62.3
	2	182.0	78.4	3.5	68.6
Bambino	1	154.3	67.2	3.0	60.2
	2	158.6	69.4	3.1	62.8
Dollar	1	140.5	60.2	2.8	56.3
	2	150.5	64.5	3.1	60.2
Roma	1	133.7	56.4	2.6	52.4
	2	128.6	59.4	2.8	56.2
SEm (±)		6.51	1.98	0.10	1.80
CD (P=0.05)		NS	NS	NS	NS

1= 1st Jun, 2= 15th Jun

The highest yield was observed for the Rio Grande-second planting date with 68.6 T/ha, followed by Bambino- second planting date with 60.2 T/ha. The lowest yield was observed for the Roma-first planting date with 52.4 T/ha. This indicates that changes in crop variety and adjusting planting dates adapting tomato to climate change. A reduction in yield for both of varieties with first planting date (1st Jun) were due to sunscald, as tomato were exposed to the direct rays of the sun during the month of September. According to Dorais et al. (2001) high light intensity can lead to disorder of tomato vegetables.

Conclusion

The primary objective of this study was to evaluate the effect of climate change and strategies for adaptation in response to climate change effect on tomato production in Ghazni province. The study is an important contribution to previous climate variability and crop production methodologies. First, the study provided a basis for further research into the consequences of climate change and the relationship between adaptation strategies. The study found that there were some variations in the minimum and maximum temperature characteristics of the area within the stipulated years under consideration in this area. The results of the present study showed that change in planting date and choice of variety could help adapting the tomato to future climate change. Changing planting time mitigated climate change impacts more than the choice of variety.

Acknowledgements

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