Effects of climate change on forage corn productivity in the southern part of Korea

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Background

Maize is easy to harvest and high productivity per unit area, so it has been cultivated as an important crop, accounting for more than 36% of food grain production worldwide (FAO, 2010; Abebe et al., 2016). Maize is a C_4 plant and is one of the crops that grow well in high-temperature environments or start growing even in cool climates with an average temperature of 10℃ or higher, and has wide climate adaptability and soil adaptability and less moisture requirements than other crops (Son et al., 2009). According to the world meteorological organization (WMO), it was reported that the global average temperature between recent 5 years (2015-2019) increased by 1.1±0.1℃ compared to 50 years (1850-1900) before industrialization (WMO, 2019). In the case of the Korean peninsula, temperatures have risen +1.2℃ over the past 30 years (1981-2010) and precipitation has increased by 77.6 mm (KMA, 2018). When applying the RCP 8.5 scenario, it is predicted that in the last of the 21st century, temperature and precipitation will increase by each +4.7℃ and +13.1% compared to the present, and subtropicalization, which is currently limited to the southern coast, will gradually move to northern regions of Korean Peninsula (KMA, 2018). The increase in temperature, the change in precipitation and the increased frequency of abnormal climate due to climate change are expected to affect all areas of the agricultural industry (Lee et al., 2012). Until now, many studies related to climate change on maize have been reported, mainly yield prediction studies using crop models based on climate change scenarios (Peichl et al, 2019; Wolf and Van Diepen, 1994) and demonstration tests using growth chamber (Abebe et al., 2016). In the case of the South Korea, a study on the development of a dry matter prediction model through regression analysis of climate factors has been reported using the database of the dry matter results from the adaptability tests of imported maize varieties (Peng et al., 2015). Recently, vulnerability assessment of forage corn for climate change has been reported in the central region of the South Korea (Chung et al., 2019), but studies on vulnerability assessment by each region to establish policies to respond to climate change are still insufficient.

Objectives

This study was conducted to use it as basic data for index development for future vulnerability evaluation by conducting a correlation analysis between the yield of forage corn and climatic factors in the southern region of the South Korea.

Materials & Methods

<Experiment design>

This study was conducted in test fields in Gyeongsangnam-do (GN; Jinju) and Jeollanam-do (JN; Naju, Jangheung) in the Southern region of Korea for 3 years from 2017 to 2019, respectively. The experimental sites was at the Jinju, Gyeongsangnam-do, Korea (35˚20' N, 128˚14' E), the Naju, Jeollanam-do, Korea (34˚97' N, 126˚55' E) and the Jangheung, Jeollanam-do, Korea (34˚55' N, 126˚89' E). In case of the Jellanam-do sites, the experiment conducted at the Naju for first year (2017) and at the Jangheung for last 2 years (2018-2019). Planting dates for each year and site are at 15th May for the Jinju and 26th May for the Naju in 2017, 14th May for the Jinju and 16th May for the Jangheung in 2018 and 14th May for the Jinju and 30th May for the Jangheung. The experimental design was a randomized plot with three blocks. Forage corn variety, Gwangpyeongok, was used in the experiment. In plots of 12 m^2, 4 rows of 4 m in length were sown at 15 cm intervals, and the rows were 75 cm apart. Chemical fertilizers were applied in different doses of nitrogen (200 kg ha^{-1}), phosphorus (150 kg ha^{-1}) and potassium contents (150 kg ha^{-1}). Approximately 50% nitrogen was applied on the sowing date, 50% at knee-high stage. Phosphorus and potassium were considered as the basis of fertilizer.

<Data collection>

Analysis of the forage corn growth characteristics, which are stem height, stem diameter, ear height, dry matter yield of stover, dry matter yield of ear, and total dry matter yield, was conducted in accordance with the Research analysis criteria for agricultural science and technology (RDA, 2012). The yield was measured the fresh weight of the two rows in the middle and dry matter yield was measured after sampling two rows per block and drying at 65℃ for 72 hours in dry oven. Meteorological data including average temperature (℃), maximum temperature (℃), minimum temperature (℃), rainfall days (day), rainfall (mm), and duration of sunshine (hours) were collected at the nearest meteorological station from the experiment sites using the Agricultural Weather Information Service (www.weather.rda.go.kr). Growing degree dasy (GDD, ℃) was calculated by [(daily maximum temperature+daily minimum temperature)/2]-10.

Results and Discussion

Table 1. Resistance of disease, insect and logging degree of forage corn

Location	Emergence (1-9)	Lodging tolerance (1-9)	Resistance to disease (1-9)	Resistance to insect (1-9)
JN	3	1	1	1
GN	2	1	1	1

Rating score: 1, excellent or strong; 9, worst or weak.
Means for 3 years in a column
Data were adapted from Min et al.(2021), J. Agric. & Life Sci., *in press.*

Table 2. Growth characteristics and dry matter yield of forage corn cultivated at the different locations in the southern region of Korea

Location	Stem diameter (cm)	Stem height (cm)	Ear height (cm)	Dry matter yield (kg·ha^{-1})		
				Stover	Ear	Total
JN	2.1±0.3[a]	215.2±25.2[b]	89.5±18.3[b]	7476±4877[a]	3998±2750[a]	11474±4682[a]
GN	2.2±0.5[a]	250.1±52.9[a]	119.8±31.4[a]	9681±4976[a]	6363±2728[a]	16045±5012[a]

[a,b] Means with the same letter in a column for each location are not differed significantly ($p<0.05$)
Means for 3 years in a column
Data were adapted from Min et al.(2021), J. Agric. & Life Sci., *in press.*

Table 3. Climatic factors in the southern region of Korea

Location	No. of growing days	Growing degree days (°C)						Rainy days (days)	Precipitation (mm)						Sunshine (h)
		May	Jun	Jul	Aug	Sep	Total		May	Jun	Jul	Aug	Sep	Total	
JN	101	80.0	382.7	526.2	441.8	149.9	1530.5	32.7	6.5	173.7	180.7	144.1	115.5	582.0	651.7
GN	103	171.5	366.5	523.2	427.6	12.5	1492.9	32.3	48.0	141.5	195.2	64.8	0.0	449.5	710.4

Means for 3 years in a column
Data were adapted from Min et al.(2021), J. Agric. & Life Sci., *in press.*

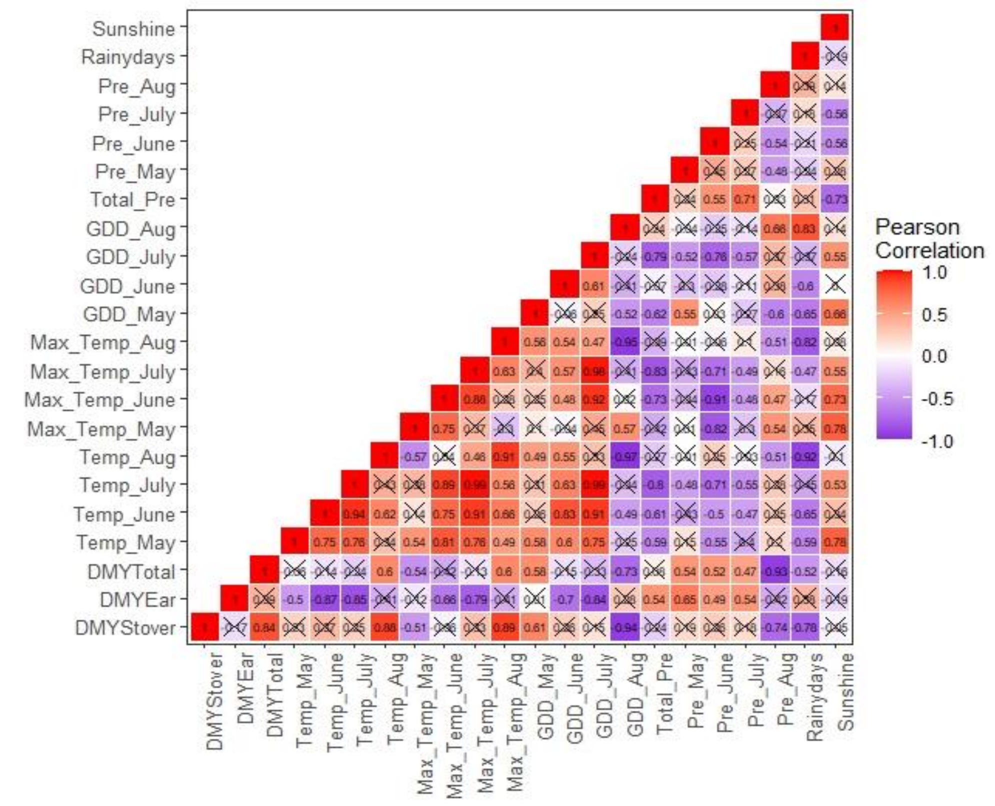

Fig. 1. Correlation coefficient between climatic factors and dry matter yield of forage corn. Data were adapted from Min et al.(2021), J. Agric. & Life Sci., *in press.*

- The emergence rate of the Jeollanam-do was lower than the Gyeongsangnam-do, which is estimated to be caused by precipitation in May (Table 1, Table 3)
- The Gyeongsangnam-do was higher in all growth characteristics of forage corn, especially 16.2% in stem height and 33.8% in ear height (Table 2)
- The total and ear dry matter of forage corn was each 39.8% and 59.1% higher in Gyongsangnam-do (Table 2)
- The higher growth day degree, precipitation in May and sunshine duration during the entire growing periods in the Gyeongsangnam-do may be the main cause for these results (Table 3)
- The total dry matter of forage corn shows a positive correlation with precipitation in May (0.54) and June (0.52) and temperature in August (Figure 1)
- The ear dry matter of forage corn shows a strong negative correlation with the average temperature (-0.85) and the average maximum temperature (-0.79) in July (Figure 1)

Conclusion

In the southern part of Korea, we confirmed that the total dry matter of maize was greatly affected by the temperature and precipitation during the cultivation period and affected by the yield of stem and leaf rather than ear. We confirmed that the yield of stem and leaf was also greatly affected by temperature and precipitation, but the effect of climate factors in each growth stage of forage corn could not be clearly revealed. So, further studies should be conducted to more accurately analyze the effect of climatic factors on forage corn growth and productivity in field.

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