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Pest Diversity in Sweet Corn [*Zea mays saccharate* (Sturt.) Bailey] in East Denpasar, Bali, Indonesia

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A B S T R A C T

Sweet corn (*Zea mays saccharate*) is cultivated in Denpasar, Bali, which is harvested when it is young for daily use, both for vegetables and for consumption, boiled or grilled. Most of the pests found were borers (*Ostrinia furnacalis*, Crambidae, Lepidoptera), flies (*Musa domistica*, Muscidae, Diptera), grasshoppers (*Locusta* sp., Acrididae, Orthoptera) and rats (*Rattus rattus*, Muridae, Rodentia). The pest diversity index ranged from 0.519-1.003, the pest dominance index ranged from 0.269-0.600 and the evenness index between species ranged from 0.094-0.700. This means that the diversity is very small, supported by a small evenness index, which also means that there are insect pests that dominate. Population dynamics of insect pests range from 0.10 to 0.21, which means the number of births and additions per day per hundred is 10 to 21 individuals. The relationship between pests and weather factors (temperature and humidity) only for borers (located on Jalan Sekarsari) has a significant positive correlation of 0.77* with the regression equation Y = 0.348 X – 24.356 (R^2 = 0.71, X = temperature and Y = borer population).

Introduction

Maize production in the Bali Province in 2019 reached 75.415 tons, while in 2020 it reached 68.094 tons (Bali Province Agriculture and Food Security Agency, 2021). One of the reasons for the decline in corn production is due to pests and diseases that disrupt corn crops. Pests are one of the factors that cause maize yield loss. Planting corn in monoculture which is carried out successively from season to season, reduces the diversity of organisms and can lead to an explosion in pest populations. Population dynamics of maize pests are the basis for assembling efficient control of major maize pests (Tenrirawe, 2013). Corn stem borer (*Ostrinia furnacalis*), cob borer (*Helicoverpa armigera*), armyworm (*Spodopteram litura*), seed fly (*Atherigona* sp.), grasshopper (*Locusta migratoria*), aphids, and rats

(*Rattus* sp.) are the nuisance organism plants that are often encountered (Adnan, 2011), there are many insect pests that disturb corn plants both during the seedling, vegetative and reproductive phases (Alejandro, 1986; O'Day *et al.,* 1998).

Bagus and Sudarma (2017) stated that pests encountered during the study included seed flies (*Atherigona* sp., Order: Diptera), grasshoppers (*Oxya chinensis* and *Locusta* sp.), Armyworms (*Spodoptera litura* F.) and caterpillars (*Helicoverpa armigera* Hbn., Noctuidae, Leppidoptera), the highest pest population was achieved by grasshoppers (38 individuals) with a population dynamic of 0.83 in 6 weeks after planting. The highest prevalence was achieved by locusts at 44.19%, followed by caterpillars at 24.42%, seed flies at 23.26% and caterpillars at 0.08%. The diversity index of 0.306 means that it is relatively small with a dominance index of 0.873 meaning that there are dominant locust pests.

Temperature and humidity determine the dynamics of maize pest populations (Lawton *et al.,* 2022). The results showed that the population of leafhoppers was highest at 36.5^{o}C and 68% relative humidity. The lowest population was observed at 31.5^{o}C and relative humidity at 75%. The highest population of jassid was found at 36^{o}C with a relative humidity of 68% and the lowest population was found at 35^{o}C with a relative humidity of 70%. The highest infestation of *Chilo partellous* was found at 32.5^{o}C relative humidity at 68% and the lowest infestation of *C.partellous* was found at 32.5^{o}C relative humidity at 50%. Overall the results of the current study indicate that relative humidity and temperature significantly affect the population of insect pests of maize plants (Zulfiqar *et al.,* 2010).

Materials and Methods

Place and time of research

The research was carried out in two places: 1) collecting samples of pests and natural enemies in the field in Sanur Village, East Denpasar District, and 2) Plant Pest Laboratory, Faculty of Agriculture, Udayana University. The research was conducted from January to March 2023.

Determining the Diversity and the Dominance Index

The diversity and dominance of pest can be determined by calculating the Shannon-Wiener diversity index (Odum, 1971) and the dominance of soil microbes is calculated by calculating the Simpson index (Pirzan and Pong-Masak, 2008).

Pest diversity index and natural enemies

The diversity index of pests and natural enemies is determined by the Shannon-Wiener diversity index, namely by the formula (Odum, 1971):

$$H' = -\sum_{i=1}^{s} Pi \ln Pi.$$

Where: H' = Shannon-Wiener diversity index

S = Number of genera

Pi = ni/N as the proportion of species i (ni = total number of individuals of total pest species i, N = total number of individuals in total n)

The criteria for assessing environmental quality can be seen in Table 1.

Dominance index

The domination index of pests and natural enemies is calculated by calculating the Simpson index (Pirzan and Pong-Masak, 2008), with the following formula:

$$C = \sum_{i=1}^{s} Pi^2$$

Where:

C = Simpson's index

S = Number of genera

Pi = ni/N, namely the proportion of individuals of type i and all individuals (ni = total number of individuals of type i, N = total number of individuals in total n)

Furthermore, the species dominance index (D) can be calculated with the 1-C formulation (Rad *et al.*, 2009). The criteria used to interpret the dominance of soil pests and natural enemies are: close to 0 = low index or lower dominance by one species of pest and natural enemy or no species dominates other species, close to 1 = large index or tends to be dominated by several species of pests (Pirzan and Pong-Masak, 2008).

Inter-species evenness index

The evenness index between species can be calculated using the formula:

E = n/N x Ln (Pi)/Ln (Pi)

Where: Pi = ni/N, namely the proportion of individuals of type i and all individuals (ni = total number of individuals of type i,

N = Number of all individuals in total n).

E = evenness index between species

Prevalence

Prevalence can be calculated by dividing the total population of certain pests and natural enemies divided by the entire population times 100%.

Calculating Population Dynamics

Pests that appeared in each experimental plot were counted for their population and type and quantitatively recorded their number from week to week during the crop growing period. The dynamics of the exponential growth of each pest population is then calculated using the Malthus formula (1798):

Nt = Noer ordN/dt = rN

Where:

No = Number of initial population, at time t = 0

Nt = Total population at time t

e = Basic natural logarithm = 2.71828

r = Reasonable constant/intrinsic speed of growth

dN = Speed of change of population/time at a given moment

dt = Time interval

Relationship Between Pest Population with Temperature and Humidity

The analysis to determine the relationship between pest populations and temperature and humidity used a regression analysis approach, and the reciprocal relationship between the two variables was calculated using correlation analysis (Gomes and Gomes, 2007).

Results and Discussion

Pest Population

The highest population development of pests found in sweet corn was obtained from a borer population (*Ostrinia furnacalis*, Crambidae, Lepidoptera) of 19.38 in the Waribang road location, followed by a borer population of 18 in the Kertalangu Village location, then followed by a borer population of 11 located on Waribang road, followed by a fly population of 10.38 on Sekarsari road, followed by a borer population of 9.75 on Sekarsari road and the smallest population of grasshoppers (*Locusta* sp., Acrididae, Orthoptera) of 1 on Waribang road (Table 2, Figure 1).

According to Rondo *et al.,* (2016) stated that the pests found during research on sweet corn in the East Denpasar area were locusts, seed flies, armyworms and cob caterpillars. Tokker and Hodgson (2023) found in their research that pests of maize plants were seed flies, armyworms, white maggots, snails, and root caterpillars.

Some pests that attack sweet corn plants include: cut caterpillars, seed flies, root caterpillars, wireworms, leaf aphids, corn leaf beetles, cob caterpillars, drooping cut caterpillars, corn borer, and corn beetles (HGIC, 2021).

Some of the pests that attack sweet corn in East Denpasar District are as follows (Figure 2):

Locusts (*Locusta* sp.) on corn plants are migratory pests where the level of damage depends on the number of populations and the type of plant attacked. The locust pest attacks especially the leaves, the leaves look damaged due to the attack of the locusts, if the population is large and the locusts are in a state of hunger, these pests can simultaneously eat up the bones of the leaves.

Stem borer (*Ostrinia fumacalis*), this pest attacks corn plants in all growth phases. Yield losses can reach 80%, high yield damage caused because the attack points are not only on certain parts, but almost all parts of the corn plant can become targets.

Seed flies (*Atherigona* sp.) are found in Java and Sumatra which can damage maize plants up to 80% and even puso.

Seed flies attack corn plants by laying eggs under the leaf surface (Ministry of Agriculture, 2020). Mouse pests have very high reproductive power because they can give birth all year round regardless of the season. The rat population is influenced by environmental factors such as water sources, nests, and food availability (Priyambodo, 2022).

Diversity and Dominance Index

The highest pest diversity index for sweet corn was obtained in Sanur Village at 1.003, followed by the pest diversity index at Sekarsari road, Sedap Malam road, Kertalangu village and Waribang road respectively of 0.964, 0.878, 0.706 and 0.519 (Table 3). This means that the index of diversity on the criteria in Sanur Village is quite stable, whereas in locations on Jalan Sekarsari, Jalan Sedap Malam and Jalan Waribang the criteria are less stable and in the location in Sanur Village the criteria are unstable (Table 1).

The domination index of pests for Sekarsari road and Sanur village respectively is 0.592 and 0.600 which is close to 1, and others such as Kertalangu Village, Jalan Waribang and Jalan Sedap Malam have domination indices of 0.393, 0.269 and 0.522 respectively, which are still below the number 1, this means that closer to number 1 there are species that dominate while those smaller than number 1 do not have species that dominate (Table 4). The index of evenness between species shows that all locations show no evenness between species (under number 1).

Population Dynamics

The dynamics of the pest population on sweet corn plants was the highest, achieved 0.70 by the grasshopper population in Sanur Village, followed by flies of 0.43 on Waribang road, the smallest was 0 in rats which were not found in Kertalangu Village (Table 4). Overall the dynamics of the insect pest population in the first week to the second week was 0.14, then the second week to the third week was 0.15 and so on until it reached 0.15 during the seventh week to the eighth week (Table 4, Figure 3).

Table.1 Criteria for assessing environmental quality (Tauruslina *et al*., 2015)

Diversity index	The condition of the community structure	Category	Scale
>2.41	Very stable	Very good	5
-2.4	More stable	Good	4
1.21 – 1.8	Stable enough	Currently	3
0.61 – 1.2	Less stable	Bad	2
<0.6	Unstable	Very bad	1

Table.2 Development of pest populations on corn plants in East Denpasar District

Location	Type of pest	Observation (week)								Amount	Average
		I	II	III	IV	V	VI	VII	VIII		
Kertalangu Vellage	Borer	28	18	21	11	10	16	20	20	144(18%)*	18
	Fly	2	0	1	4	14	4	7	5	37(5%)	4.63
	Mouse	0	0	0	0	0	1	0	1	2(0%)	0.25
	Grasshopper	0	0	0	0	0	4	1	4	9(1%)	2
Waribang Road	Borer	14	20	19	21	22	19	22	18	155(19%)	19.38
	Fly	2	3	2	4	3	2	1	3	20(2%)	2,43
	Grasshopper	1	0	1	2	0	2	1	1	8(1%)	1
Sekarsari Road	Borer	5	6	8	10	11	12	13	13	78(10%)	9.75
	Fly	10	11	10	9	10	10	11	12	83(10%)	10.38
	Grasshopper	2	3	3	2	2	2	3	4	21(3%)	2.63
Sedap Malam Road	Borer	9	10	10	11	11	12	12	13	88(11%)	11
	Fly	2	3	2	3	4	4	4	5	27(3%)	3.38
	Grasshopper	1	2	2	3	4	3	3	3	21(3%)	2,63
Sanur Vellage	Borer	6	7	8	6	7	8	9	10	61(8%)	7.63
	Fly	2	3	4	5	4	4	3	6	31(4%)	3.88
	Grasshopper	3	2	2	2	3	4	2	3	21(3%)	2.63
		87	88	93	93	105	107	112	121	806	

*Numbers in brackets mean prevalence (dominance)

Table.3 Index of diversity and dominance of insect pests on sweet corn plants

Location	Indexes		
	Diversity (H')	Domination (D)	Evenness between species (E)
Kertalangu village	0.706	0.393	0.700
Waribang road	0.519	0.269	0.094
Sekarsari road	0.964	0.592	0.252
Sedap Malam road	0.878	0.522	0.247
Sanurvellage	1.003	0.600	0.280

Table.4 Table of population dynamics of insect pests on sweet corn plants

Location	Type of pest	Observation (week)						
		I	II	III	IV	V	VI	VII
Kertalangu vellage	Borer	0.09	0.17	0.07	0.13	0.27	0.17	0
	Fly	0	0	0.57	0.50	0.04	0.25	0.08
	Mouse	0	0	0	0	0	0	0
	Grasshopper	0	0	0	0	0	0,04	0.57
Waribang Road	Borer	0.20	0.15	0.16	0.15	0.17	0.17	0.12
	Fly	0.21	0.10	0.29	0.11	0.10	0.07	0.43
	Grasshopper	0	0	0.29	0	0	0.07	0.14
Sekarsari Road	Borer	0.17	0.19	0.17	0.16	0.16	0.15	0.14
	Fly	0.16	0.13	0.13	0.16	0.14	0.16	0.16
	Grasshopper	0.21	0.15	0.10	0.14	0.14	0.21	0.19
Sedap Malam Road	Borer	0.16	0.14	0.16	0.14	0.16	0.14	0.15
	Ply	0.21	0.10	0.21	0.19	0.14	0.14	0.18
	Grasshopper	0.29	0.14	0.21	0.19	0.11	0.14	0.14
Sanurvellage	Borer	0.17	0.16	0.11	0.17	0.16	0.16	0.08
	Fly	0.21	0.19	0.18	0.11	0.14	0.11	0.29
	Grasshopper	0.10	0.14	0.14	0.21	0.19	0.70	0.21
Amount of population dinamics		**0.14**	**0.15**	**0.14**	**0.16**	**0.10**	**0.21**	**0.15**

Table.5 Correlation and regression relationship between pests and temperature and humidity

Parameters	Correlation coefficient		Regression formula
	Temperature	Relative humidity	
Kertalanguvellage			
Boer	-0.70	-0.20	
Fly	-0.56	0.55	
Grasshopper	0.41	0.70	
Waribang road			
Borer	-0.34	-0.46	
Fly	-0.27	-0.56	
Grasshopper	0.04	-0.17	
Sekarsari road			
Borer	0.77*	-0.50	Y_1 = 0,3481 X_1 + 24,356 (R^2 = 0.71, X = Temperature, Y = borer population)
Fly	0.59	0.08	
Grasshopper	0.57	0.05	
Sedap Malam road			
Borer	0.57	0.70	
Fly	0.50	0.45	
Grasshopper	0.68	0.33	
Sanurvellage			
Borer	0.13	-0.02	
Fly	0.05	-0.39	
Grasshopper	0.40	0.32	

Fig.1 Population of pests on sweet corn in East Denpasar District

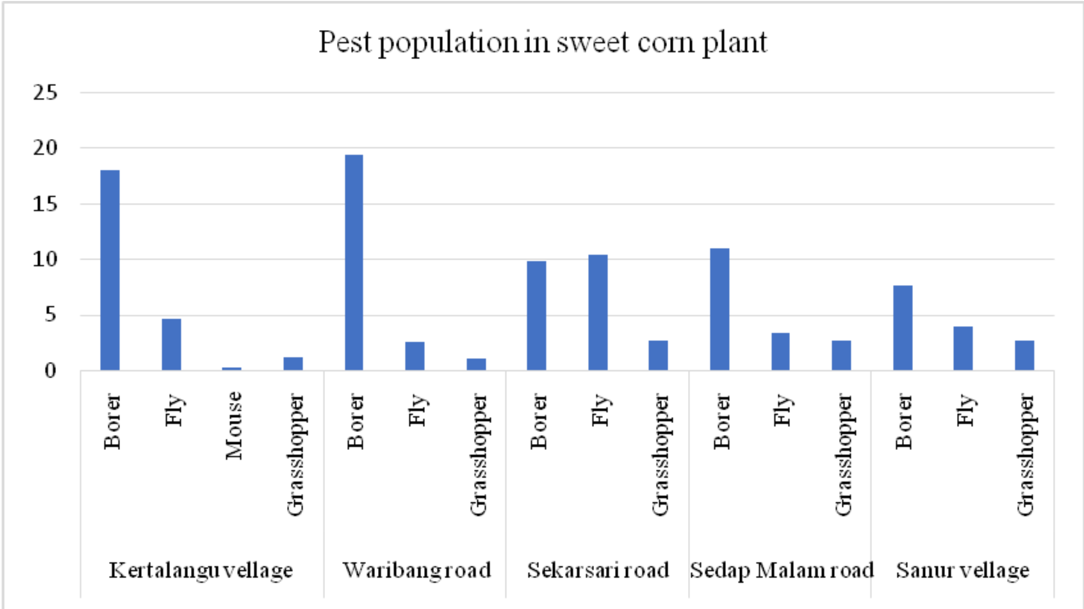


Fig.2 Types of pests that attack sweet corn in East Denpasar District (A = grasshoppers, B = borers, C = flies and D = symptoms of corn cobs being eaten by rats)

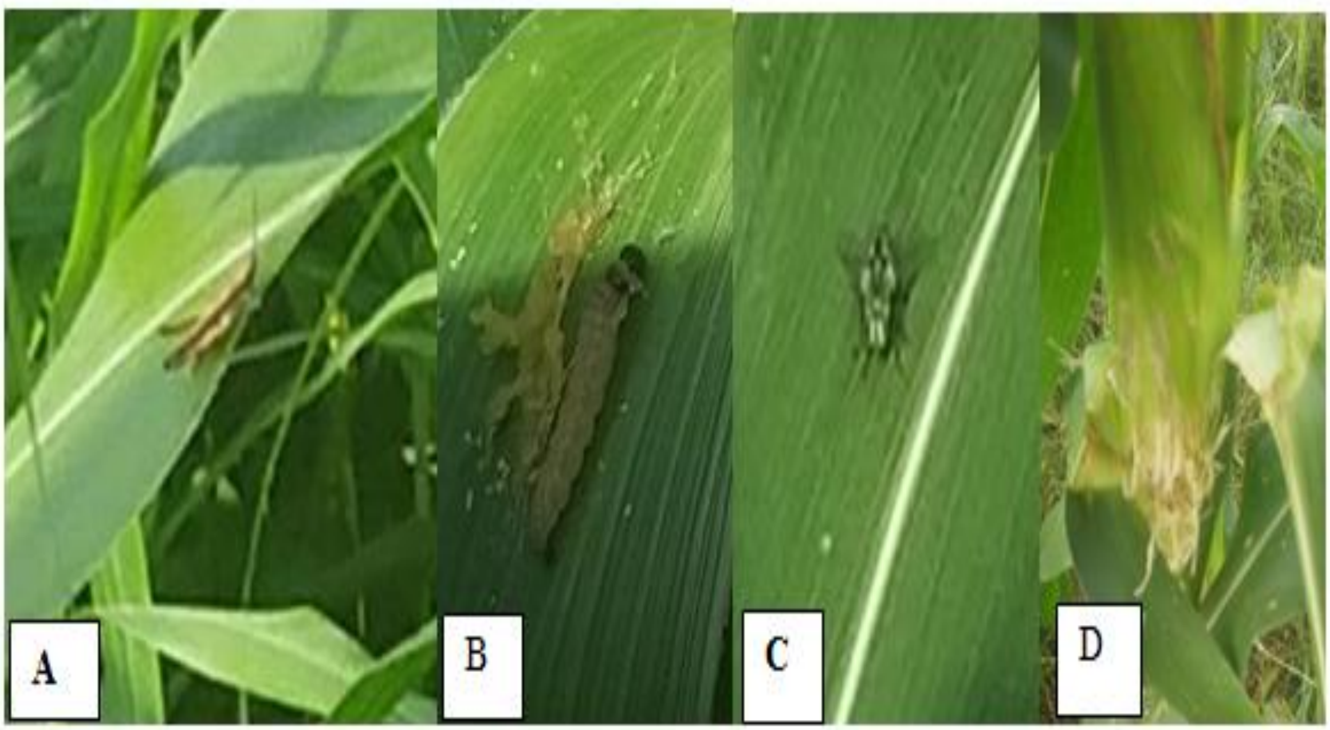


Fig.3 Population dynamics of insect pests on sweet corn plants

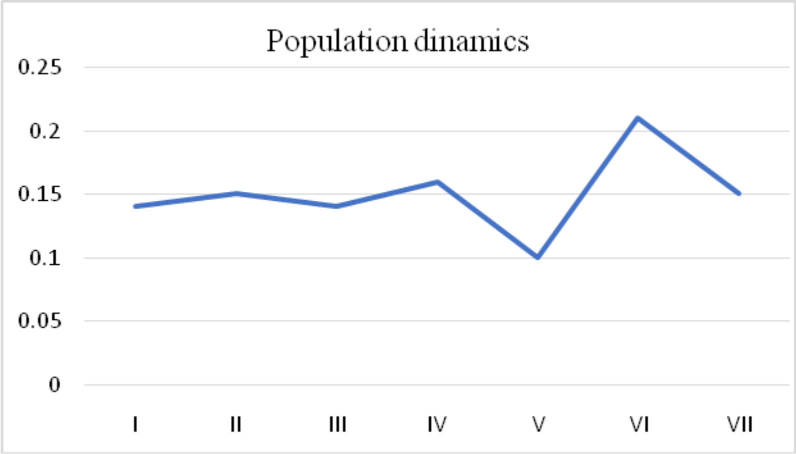
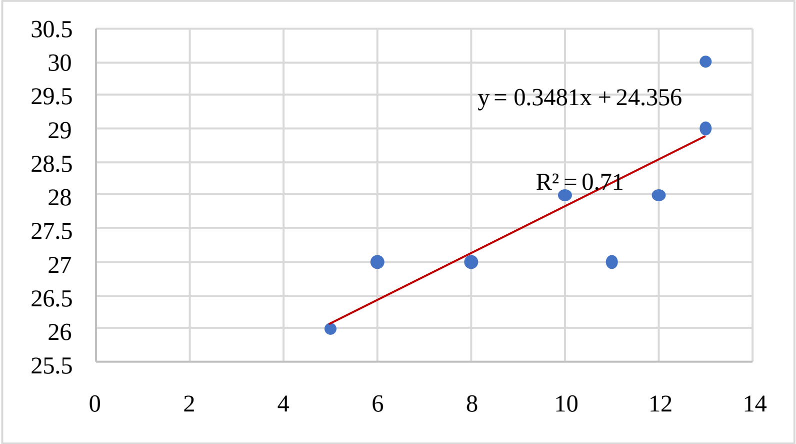


Fig.4 Regression relationship between borers and temperature at the location Sekarsari road on sweet corn plants



Factors that determine the high or low population of an organism consist of internal, external and food factors. Insect internal factors include life cycle, sex ratio and personality. The life cycle is the length of time the insect develops from the egg until the insect lays its first egg.

The shorter the life cycle, the faster the population growth. Sex ratio is the ratio of male and female insects, the more females produced the faster the insect population will develop, and personality, namely the number of eggs produced by a female, of course the higher the level of personality the faster the insect population will develop (Dadang, 2006).

Relationship Between Pests and Weather Factors

The correlation between pests and weather factors (temperature and humidity) only for borers at the Sekarsari road location shows a positively significant relationship (Table 5, Figure 4), and the regression relationship with the formula Y = 0.348 X + 24.356 (R^2 = 0.71, X = temperature, Y= borer population.

The higher the temperature, to a certain extent, the higher the population of borer pests. Temperature is very decisive in the personality of insect pests. Insect pests lay eggs and reproduce depending on the ambient temperature. This is in line with the results of a study by Widhayasa and Surya Darma (2022), which stated that the armyworm population (*Spodoptera frugiperda* (Lepidoptera: Noctuidae) on corn plants in East Kalimantan had a significant correlation with positive temperature and negative significant humidity. Arshad *et al.,* (2021) stated that at higher temperatures there was a significant increase in the pest population with a relative humidity of 46% and a temperature of 40^{o}C.

Climate change is one of the factors driving the spread of pests and diseases, along with increasing global trade. Climate change can affect population sizes, survival rates and geographic distribution of pests; and the intensity, progression and geographical distribution of the disease. Temperature and rainfall are big drivers of shifts in how and where pests and diseases spread, according to experts. In general, increased temperatures and rainfall levels favour the growth and distribution of most pest species by providing a warm, moist environment and providing the moisture necessary for their growth, says Tek Sapkota, agri-systems scientist and climate change International Maize and Wheat Improvement Center (CIMMYT). (Doody, 2020). The warming climate will accelerate the phenological development because the number of thermal units required for leaf appearance is relatively constant in the vegetative stage. Productivity of corn is reduced when extreme temperature events occur during pollination and is further exaggerated when there are water deficits at pollination. During the grain-filling period, warm temperatures above the upper threshold cause a reduction in yield. Model estimates suggest that for every 1°C increase in temperature there is nearly a 10% yield reduction. To meet world demand, new adaptation practices are needed to provide water to the growing crop and avoid extreme temperature events during the growing season. Climate change will continue to affect corn production and understanding these effects will help determine where future production areas exist and innovative adaptation practices to benefit yield stability could be utilized (Hatfield and Dold, 2018).

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