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Changes In Yield Components Of Maize Genotypes Under Moisture Stress Condition

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ABSTRACT
Drought, one of the environmental stresses, is the most significant factor restricting plant production in majority of agricultural fields of the world. A field experiment was conducted to evaluate the effect of moisture stress on yield and yield components of maize genotypes during rabi, 2015-16 and rabi, 2016-17 at Dry Land Farm, S.V. Agricultural College, Tirupati. The experiment was laid out in a split plot design with moisture levels as the main plot and genotypes as the sub plots. Moisture stress at soft dough stage showed significant effect on yield and yield components of maize genotypes, compared to irrigated control. Yield components viz., number of cobs m^{-2}, 100 kernel weight, cob yield as well as kernel yields were significantly reduced due to moisture stress. Kernel yield was significantly decreased to the extent of 48 and 53 per cent during rabi, 2015-16 and 2016-17 respectively due to moisture stress. The genotypes PDM 1465, PDM 1452 and PDM 1498 maintained sturdily higher yield and its components followed by PDM 1428 and PDM 1474. Genotypes PDM 1474, PDM 1479 recorded moderate yield. The genotypes PDM 1439 and PDM 1409 recorded lower yields under imposed moisture stress conditions. Similar trend was recorded with harvest index and shelling percent.
Key words: Drought, Maize, Moisture stress, Yield components.

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INTRODUCTION

Maize is the third most important cereal after wheat and rice all over the world serving as staple food for many countries. In India, maize is cultivated in an area of about 9.18 million ha with production of 24.17 million tonnes and productivity of 2632 kg ha-1. In Andhra Pradesh it is cultivated in an area of 3.03 lakh ha with production of 19.38 lakh tonnes and productivity of 4234 kg ha-1. Abiotic stresses are the primary cause of crop loss worldwide reducing average yields in major crop plants, including maize by more than 50 per cent. Among the abiotic stresses, drought is the severe limiting factor for maize production [2].

Maize is susceptible to drought and is sensitive to water stress at grain filling stage. Maize was more sensitive to drought particularly during reproductive phase and equally sensitive in the dryland and non-dryland regions. In dry land regions, water stress and high temperature are regarded as severe constraints to maize production even under conditions where the soil profile is fully recharged at the beginning of the growing season. Daryanto *et al*. [3] observed 39.3 per cent yield reduction in maize at approximately 40 per cent water reduction.

Screening and selection of plants of different crops with considerable water stress tolerance has been considered an economic and efficient means of utilizing drought-prone areas when combined with appropriate management practices to reduce water loss [11]. Physiological changes due to stress which reflect an adaptive mechanism in a genotype are worth measuring for relative assessment of differences. Different physiological traits along with morphological traits viz. root length, cobs per plant and grain yield are of great adaptive value for selection of drought tolerant lines [7]. Hence the present experiment was conducted in order to evaluate the effect of moisture stress on yield and yield components of maize genotypes.

MATERIALS AND METHODS

The present experiment was conducted during *rabi* 2015-16 and *rabi* 2016-17 at dry land farm, S.V. Agricultural College, Tirupati with 12 genotypes (selected through PEG-6000 experiment). The experiment was laid out in a split plot design with two main treatments, twelve sub treatments and replicated thrice. Main Treatments: 2: i) Irrigated (control) ii) Imposed moisture stress at soft dough stage (60-80 DAS), Sub Treatments: 12 Genotypes, which includes ten tolerant (PDM 1409, PDM 1415, PDM 1428, PDM 1452, PDM 1465, PDM 1474, PDM 1479, PDM 1485, PDM 1488, PDM 1498) and two susceptible (PDM 1430, PDM 1439) genotypes. The experiment was laid out in sandy loam soil with the plot size of 3 × 2 m^2. Recommended dose of fertilizers were applied. In case of irrigated treatment, irrigations were applied at regular intervals, whereas in moisture stress treatment irrigation was withheld from 60 to 80 DAS (Soft dough stage) and no rainfall was received during this period. Prophylactic measures were taken for protecting the crop from pests. Number of cobs in one m^{-2} area was counted and expressed as number of cobs m^{-2}. Length of the cob was measured in centimetres from the base to the tip after dehusking. Number of rows for each cob of the five plants was counted, averaged and expressed as number of rows per cob. The cob yield and kernel yield obtained from each net plot was weighed and expressed in q ha^{-1}. Hundred kernels at random were counted, weighed and recorded as hundred kernel weight. Shelling percentage was calculated by the following formula and expressed in percentage.

$$\text{Shelling per cent} = \frac{\text{Kernel yield}}{\text{Cob yield}} \times 100$$

Harvest Index (HI) was expressed as the ratio of seed yield to biological yield and was calculated as given below.

$$\text{HI (\%)} = \frac{\text{Economic (grain) yield}}{\text{Biological (grain + stover) yield}} \times 100$$

The experimental data were analyzed statistically by following standard procedure outlined by Panse and Sukhatme [10].

RESULTS AND DISCUSSION:

Yield in crop plants is an ultimate expression and depends upon the expressibility of many other characters called yield components.

Cob Yield (q ha^{-1})

During both the years of experiment significant differences were noticed between moisture stress treatments and genotypes. Significant interaction effect was found during first experiment. Maryam Goodarzian *et al*. [6] reported that drought stress had a significant effect on grain yield and its components of maize plants. The possible decrease in stomatal conductance and leaf area resulting in loss of dry matter accumulation partly explains the decrease in yield and yield components under moisture stress [13].

Mean cob yield was significantly reduced to the extent of 43 and 48 per cent during *rabi,* 2015-16 and 2016-17 respectively due to imposition of moisture stress at soft dough stage. Among the genotypes PDM 1452 (46.7, 43.4 q ha^{-1}) and PDM 1465 (47.1, 42.9 q ha^{-1}) recorded significantly higher cob yield followed by and PDM 1498 (43.8, 39.5), PDM 1428 (39.2, 34.4 q ha^{-1}) during both the years of study (Table 1). These genotypes are proved to be high yielders under irrigated as well as moisture stress conditions. Genotypes PDM 1474 (34.7, 29.9 q ha^{-1}), PDM 1479 (34.1, 29.1 q ha^{-1}) recorded moderate yield. However, the genotypes PDM 1439 (27.4, 23.5 q ha^{-1}), PDM 1409 (28.2 and 25.2 q ha^{-1}) and PDM 1430 (32.6, 26.6 q ha^{-1}) recorded poor yield under moisture stress conditions, despite of recording moderate yields under irrigated conditions. Similar results of decrease in the grain yield due to moisture stress was reported in prosomillet [14].

Number of Rows Cob^{-1}

Due to moisture stress at soft dough stage, no of rows cob^1 was significantly decreased to the extent of 7.8 and 8.2 per cent during *rabi,* 2015-16 and 2016-17 respectively (Table 1). Genotypes PDM 1498 (15.32, 14.89), PDM 1415 (15.46, 12.82) recorded significantly higher number of cobs followed by PDM 1452 (15.36, 14.74) during both the years of study. Genotypes PDM 1439 (13.26, 13.05), PDM 1474 (13.33, 12.93), PDM 1430 (13.71, 12.61) recorded significantly lower number of rows per cob.

Number of Cobs m^{-2}

Due to imposition of moisture stress at soft dough stage, no of cobs m^{-2} was significantly decreased to the extent of 32 and 35.2 per cent during *rabi,* 2015-16 and 2016-17 respectively. Significant differences were observed between genotypes tested. Among the genotypes PDM 1452 (7.67, 7.43) recorded significantly higher number of cobs followed by PDM 1465 (6.58, 5.92), PDM 1498 (7.42, 7.15) PDM 1428 (6.04, 6.19) during both the years of study (Table 2). Similar results were reported in maize by Rajendrakumar *et al*. [12].

Length of Cob (cm)

During both the years of experiment significant differences were noticed between moisture stress treatments and genotypes. However interaction effect was non significant. Length of cob was significantly decreased to the extent of 9.9 and 10 per cent during *rabi,* 2015-16 and 2016-17 respectively (Table 2). Among the genotypes PDM 1465 (17.34, 16.82 cm) and PDM 1498 (17.32, 16.04 cm) recorded significantly higher cob length followed by PDM 1452 (17.30, 14.98 cm), PDM 1428 (17.18, 16.53 cm) during both the years of study. Genotypes PDM 1439 (12.64, 13.10 cm), PDM 1430 (13.29, 12.09 cm) recorded significantly lower cob length. Sharma (1987) [15] reported that under drought condition, grain yield was positively associated with cob length. Moisture stress at different maize growth stages had a significant influence ($p<0.05$ and $p<0.01$) on cob diameter and cob length [4].

Kernel Yield (q ha^{-1})

During both the years of experiment significant differences were noticed between moisture stress treatments, genotypes and their interactions (Table 3). Kernel yield was significantly decreased to the extent of 48 and 53 per cent during *rabi,* 2015-16 and 2016-17 respectively due to moisture stress. Jurgens *et al*. [5] reported that drought stress during grain filling period primarily affects kernel weight due to decrease in leaf carbon exchange rates. Muhammad [9] stated that extreme water stress at different stages of crop development reduced the grain yield up to 50 percent.

Genotype PDM 1452 recorded significantly higher kernel yield followed by PDM 1465, PDM 1498 and PDM 1428 during both the years of study. Genotypes PDM 1409, PDM 1439, PDM 1430 recorded significantly lower kernel yield. Similar significant variability among maize genotypes under drought were reported by Abdelmula and Sabiel [1] and stated that effect of drought on genotypes was significant for kernel yield.

The genotype PDM 1452 which maintained higher growth and physiological attributes recorded highest kernel yield compared to all other genotypes in both irrigated as well as imposed moisture stress condition. Mostafavi *et al*. [8] reported that grain yield reduction of maize due to the drought pressure is varied between 1 to 76 per cent depending on the severity, timing and stage of occurrence found that grain yield was reduced to 37 per cent because of 18 per cent kernel weight reduction and 1 per cent reduction in the number of kernel.

Hundred Kernel Weight (g)

Moisture stress significantly decreased hundred kernel weight to the extent of 9.3 and 13.7 per cent during *rabi,* 2015-16 and 2016-17 respectively. Jurgens *et al*. [5] reported that drought stress during soft dough period primarily affects kernel weight due to decrease in leaf carbon exchange rates. Genotypes PDM 1465 (28.61, 26.17 g) and PDM 1452 (27.66, 23.87 g) recorded significantly higher 100 kernel weight followed by and PDM 1498 (26.04, 24.25 g), PDM 1428 (25.35, 24.61 g) during both the years of study (Table 3). Genotypes PDM 1439 (22.79, 21.61 g), PDM 1430 (22.67, 21.10 g) recorded significantly lower 100 kernel weight.

Shelling Percentage

Shelling per cent was significantly decreased to the extent of 8.76 and 7.08 per cent during *rabi,* 2015-16 and 2016-17 respectively due to imposition of moisture stress (Table 4). During both the years of study numerical differences were observed between genotypes tested. Genotypes PDM 1498 and PDM 1409 recorded higher shelling percentage followed by PDM 1462 and PDM 1465 during both the years of study. Genotypes PDM 1428, PDM 1485 recorded lower shelling percentage.

Harvest Index (%)

Harvest index is one of the major components for higher grain yields. Harvest index was significantly decreased to the extent of 11.3 and 20 per cent during *rabi,* 2015-16 and 2016-17 respectively. Numerical differences were observed between genotypes tested. PDM 1479, PDM 1465 and PDM 1452 recorded higher HI followed by and PDM 1498, PDM 1428 during both the years of study (Table 4). Genotypes PDM 1439, PDM 1430, PDM 1409 recorded significantly lower HI. Elias Meskelu *et al*. (2014) revealed that when combined moisture stress at development and mid season growth stage happen, cob diameter, cob length and harvest index are highly affected which have a direct relation with grain yield.

Table 1.Evaluation of maize genotypes for number of rows cob^{-1} and cob yield (q ha^{-1}) under imposed moisture stress condition

Genotypes	Rabi 2015-16						Rabi 2016-17					
	No of rows cob-1			Cob yield (q ha-1)			No of rows cob-1			Cob yield (q ha-1)		
	M0	M1	Mean	M0	M1	Mean	M0	M1	Mean	M0	M1	Mean
PDM 1409	15.22	14.89	15.06	39.8	16.5	28.2	14.63	13.11	13.87	36.75	13.67	25.2
PDM 1415	16.80	14.11	15.46	41.3	20.5	30.9	12.05	13.58	12.82	47.28	16.26	31.8
PDM 1428	14.22	13.33	13.78	48.0	30.4	39.2	14.88	13.13	14.01	43.25	25.54	34.4
PDM 1452	15.83	14.89	15.36	52.9	40.4	46.7	15.18	14.29	14.74	50.04	36.75	43.4
PDM 1465	14.66	14.08	14.37	58.1	36.1	47.1	15.45	13.96	14.71	52.98	32.88	42.9
PDM 1474	13.88	12.78	13.33	42.2	27.2	34.7	13.71	12.14	12.93	39.78	20.04	29.9
PDM 1479	15.64	14.55	15.10	41.4	26.8	34.1	12.61	11.89	12.25	38.97	19.29	29.1
PDM 1485	14.94	12.55	13.75	38.1	20.5	29.3	12.95	11.55	12.25	37.42	18.42	27.9
PDM 1488	15.30	14.28	14.79	39.8	19.1	29.5	14.98	13.54	14.26	35.33	17.81	26.6
PDM 1498	15.64	14.99	15.32	54.9	32.6	43.8	15.76	14.02	14.89	50.31	28.67	39.5
PDM 1430	14.22	13.20	13.71	45.0	20.2	32.6	13.33	11.89	12.61	39.03	14.25	26.6
PDM 1439	14.00	12.52	13.26	40.3	14.4	27.4	13.77	12.33	13.05	33.78	13.25	23.5
Mean	15.03	13.85		45.2	25.4		14.11	12.95		42.08	21.40	
	T	G	T × G	T	G	T × G	T	G	T × G	T	G	T × G
SE m ±	0.02	0.65	0.06	0.61	0.70	2.12	0.01	0.61	0.04	0.19	1.55	0.66
CD (P=0.05)	0.10	NS	NS	3.77	2.01	3.81	0.08	1.74	NS	1.17	4.41	NS

M_0 : Irrigated control; M_1 : Imposed moisture stress at soft dough stage (60-80 DAS)

Table 2.Evaluation of maize genotypes for number of cobs m^{-2} and length of cob (cm) under imposed moisture stress condition

Genotypes	Rabi 2015-16						Rabi 2016-17					
	No. of cobs m-2			Length of Cob (cm)			No of cobs m-2			Length of Cob (cm)		
	M0	M1	Mean	M0	M1	Mean	M0	M1	Mean	M0	M1	Mean
PDM 1409	6.08	3.75	4.92	16.17	13.75	14.96	7.88	3.10	5.49	16.27	13.85	15.06
PDM 1415	8.17	5.50	6.83	18.31	15.03	16.67	7.16	5.29	6.22	17.25	13.97	15.61
PDM 1428	7.00	5.08	6.04	17.70	16.65	17.18	7.50	4.88	6.19	17.05	16.00	16.53
PDM 1452	8.33	7.00	7.67	17.68	16.92	17.30	8.01	6.85	7.43	15.11	14.85	14.98
PDM 1465	7.92	5.25	6.58	17.79	16.88	17.34	7.52	4.33	5.92	17.27	16.36	16.82
PDM 1474	6.92	4.50	5.71	17.75	15.76	16.76	7.12	4.83	5.97	17.27	15.28	16.28
PDM 1479	6.75	4.42	5.58	16.59	15.67	16.13	6.97	4.76	5.86	15.25	14.33	14.79
PDM 1485	5.67	4.58	5.13	16.82	14.41	15.62	6.89	4.38	5.64	15.52	13.11	14.32
PDM 1488	5.92	4.33	5.13	17.07	16.81	16.94	6.56	4.28	5.42	17.05	16.29	16.67
PDM 1498	8.50	6.33	7.42	17.52	16.93	17.23	8.20	6.09	7.15	16.33	15.74	16.04
PDM 1430	7.83	4.53	6.18	16.14	13.29	14.72	7.22	4.19	5.71	14.94	12.09	13.52
PDM 1439	7.95	3.93	5.94	15.66	12.64	14.15	7.58	4.39	5.99	15.12	13.10	14.11
Mean	7.25	4.93		17.10	15.40		7.38	4.78		16.20	14.58	
	T	G	T × G	T	G	T × G	T	G	T × G	T	G	T × G
SE m ±	0.02	0.29	0.08	0.02	0.74	0.07	0.02	0.29	0.08	0.02	0.70	0.07
CD (P=0.05)	0.14	0.81	NS	0.12	2.10	NS	0.14	0.81	1.16	0.12	1.99	NS

M_0 : Irrigated control; M_1 : Imposed moisture stress at soft dough stage (60-80 DAS)

Table 3.Evaluation of maize genotypes for kernel yield (q ha^{-1}) and 100 Kernel weight (g) under imposed moisture stress condition

Genotypes	*Rabi* 2015-16						*Rabi* 2016-17					
	Kernel yield (q ha^{-1})			100 Kernel weight (g)			Kernel yield (q ha^{-1})			100 Kernel weight (g)		
	M_0	M_1	Mean	M_0	M_1	Mean	M_0	M_1	Mean	M_0	M_1	Mean
PDM 1409	33.0	11.4	**22.2**	26.81	23.63	**25.22**	30.35	10.04	**20.2**	25.11	22.04	**23.58**
PDM 1415	32.8	15.4	**24.1**	29.36	23.13	**26.25**	37.86	11.50	**24.7**	26.54	20.38	**23.46**
PDM 1428	37.5	22.4	**30.0**	26.03	24.66	**25.35**	32.21	18.42	**25.3**	26.89	22.32	**24.61**
PDM 1452	43.1	31.1	**37.1**	29.31	26.01	**27.66**	41.60	29.71	**35.7**	26.32	21.42	**23.87**
PDM 1465	45.8	26.8	**36.3**	29.86	27.36	**28.61**	41.87	24.48	**33.2**	27.19	25.15	**26.17**
PDM 1474	34.0	20.8	**27.4**	27.21	24.63	**25.92**	32.12	15.36	**23.7**	25.11	22.46	**23.79**
PDM 1479	32.5	19.6	**26.1**	25.17	24.45	**24.81**	31.01	13.59	**22.3**	24.59	23.28	**23.94**
PDM 1485	31.2	14.3	**22.8**	28.68	25.32	**27.00**	31.03	13.03	**22.0**	27.68	22.33	**25.01**
PDM 1488	31.7	13.6	**22.6**	26.63	25.07	**25.85**	28.25	12.74	**20.5**	25.88	23.69	**24.79**
PDM 1498	45.2	24.5	**34.9**	26.77	25.31	**26.04**	41.86	22.69	**32.3**	26.93	21.57	**24.25**
PDM 1430	34.9	14.1	**24.5**	23.62	21.72	**22.67**	30.66	11.03	**20.8**	22.36	19.83	**21.10**
PDM 1439	33.5	10.2	**21.9**	23.89	21.69	**22.79**	25.85	10.04	**17.9**	22.75	20.46	**21.61**
Mean	**36.3**	**18.7**		**26.95**	**24.42**		**33.72**	**16.05**		**25.61**	**22.08**	
	T	**G**	**T × G**	**T**	**G**	**T × G**	**T**	**G**	**T × G**	**T**	**G**	**T × G**
SE m ±	**0.61**	**0.70**	**2.12**	**0.03**	**1.15**	**0.00**	**0.15**	**1.23**	**0.52**	**0.03**	**1.07**	**0.09**
CD (P=0.05)	**3.77**	**2.01**	**3.81**	**0.16**	**3.28**	**NS**	**0.93**	**3.50**	**4.99**	**0.17**	**NS**	**NS**

M_0 : Irrigated control; M_1 : Imposed moisture stress at soft dough stage (60-80 DAS)

Table 4.Evaluation of maize genotypes for Shelling percentage and harvest index (%) under imposed moisture stress condition

Genotypes	*Rabi* 2015-16						*Rabi* 2016-17					
	Shelling percentage			Harvest index (%)			Shelling percentage			Harvest index (%)		
	M_0	M_1	Mean	M_0	M_1	Mean	M_0	M_1	Mean	M_0	M_1	Mean
PDM 1409	82.99	77.55	**80.27**	40.11	37.53	**38.82**	82.58	73.48	78.03	41.70	34.94	**38.32**
PDM 1415	79.34	76.15	**77.74**	43.46	38.93	**41.20**	80.09	70.75	75.42	46.21	35.18	**40.70**
PDM 1428	76.44	71.76	**74.10**	45.91	37.65	**41.78**	74.47	72.10	73.29	48.25	34.31	**41.28**
PDM 1452	81.47	73.74	**77.61**	44.32	41.38	**42.85**	83.12	80.84	81.98	47.97	36.73	**42.35**
PDM 1465	78.83	74.24	**76.53**	46.46	39.91	**43.19**	79.04	74.45	76.75	48.67	36.7	**42.69**
PDM 1474	83.08	71.48	**77.28**	44.14	35.31	**39.73**	80.74	76.64	78.69	46.31	32.14	**39.23**
PDM 1479	84.18	69.40	**76.79**	45.82	41.11	**43.47**	79.57	70.43	75.00	48.85	37.08	**42.97**
PDM 1485	81.94	69.76	**75.85**	41.66	38.25	**39.96**	82.93	70.75	76.84	44.65	34.26	**39.46**
PDM 1488	82.46	71.20	**76.83**	43.16	36.79	**39.98**	79.95	71.52	75.74	45.48	33.47	**39.48**
PDM 1498	82.33	78.26	**80.30**	45.43	40.54	**42.99**	83.21	79.14	81.18	48.31	36.66	**42.49**
PDM 1430	77.66	75.79	**76.73**	39.33	36.11	**37.72**	78.55	77.38	77.97	42.22	32.22	**37.22**
PDM 1439	80.25	76.57	**78.41**	40.20	37.64	**38.92**	76.53	75.80	76.17	41.43	35.41	**38.42**
Mean	80.92	73.83		43.33	38.43		80.07	74.44		45.84	35.93	
	T	**G**	**T × G**	**T**	**G**	**T × G**	**T**	**G**	**T × G**	**T**	**G**	**T × G**
SE m ±	**0.04**	**3.45**	**0.16**	**0.04**	**1.84**	**0.14**	**0.04**	**3.48**	**0.13**	**0.09**	**1.85**	**0.32**
CD (P=0.05)	**0.28**	**NS**	**NS**	**0.24**	**NS**	**NS**	**0.23**	**NS**	**NS**	**0.57**	**NS**	**NS**

M_0 : Irrigated control; M_1 : Imposed moisture stress at soft dough stage (60-80 DAS)

CONCLUSION

Moisture stress at soft dough stage showed significant effect on final yields of maize genotypes, compared to irrigated control. However interaction effects between genotypes and irrigated treatments showed only numerical variations. The maize genotypes differed in their response to moisture stress in terms of yield and yield components. The genotypes PDM 1465, PDM 1452 and PDM 1498 recorded higher yield and its components followed by PDM 1428 and PDM 1474. The genotypes PDM 1439 and PDM 1409 recorded lower yields under imposed moisture stress conditions.

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