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Research Article
Evaluation the Adaptability of Different Corn Cultivars under Drought Stress at Different Growth Stages

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Abstract

Background and Objective: Drought stress severely affects corn growth and development during its whole life cycle by altering cell division and leading to changes in plant morphology, reducing anthesis-silking interval and consequently results in poor yield. The aim of this research was to evaluate the adaptability of corn cultivars under various drought stress conditions at different growth stages. **Materials and Methods:** This research was conducted in green house condition during April to September 2017 at the Department of Agronomy, Faculty of Agriculture and Kasetsart University (KU). Four corn cultivars (SW4452, NS-3, NT6248 and NT7328) were tested under factorial in randomized complete block design (RCBD). There were three blocks where drought stress was executed in block wise. The block one executed at vegetative stage (30DAP), block two at flowering stage (60DAP) and block three at grain formation stage (76DAP).Drought stress adaptability of those cultivars at seedling stage was tested under growth chamber where germination data were collected on 21 days after germination. The physiological, morphological, roots properties and crop yield data were collected. **Results:** The result on maximum germination and T50 percentage showed highly statistical significant different at $p<0.05$ level for NT7328 and NT6248, respectively. The number of roots, root length, roots fresh and dry weight and root-shoots ratio was significantly different for Ns-3. Furthermore, the yield production (t h^{-1}) according to the period imposed to drought stress were 4.06, 3.69 and 2.85 t h^{-1} for vegetative, flowering and grain formation stage. However high yield value within cultivars were 3.7, 3.4 and 2.6 and 4.2 t h^{-1} for SW4452, NS-3, NT6248 and NT7328, respectively. **Conclusion:** Finally the result showed high drought adaptability to NT7328 and SW4452 while NT6248 cultivars was seems to be vulnerable to drought stress.

Key words: Drought stress, corn cultivars, drought adaptability, growth stages

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Drought is a potential limited factor on crop production because is not easy for the farmer to control this problem[1]. Not only drought but also high temperatures affect greatly the corn production. The yield decreased by 31-43% under slowest warming scenario and will be decreased by 67-79% under the most rapid warming scenario at the end of the century[2].

Corn seed called kernel have three major parts includes, fruits wall, endosperm and embryo. Corn is monoecious plant which means that have both male (tassel) and female (ear) flower together. The tassel produce pollen then the pollen pollinated the female flowers which develop into kernels. Tassel have many lateral blanches with many pollen which facilitate the pollination. Pollination may take 5-8 days. However, the soil nutrient accelerate scorn growth but the crop maturation will differ from 70-210 days according to cultivars and weather condition. The corn are advised to be harvested when the grain moisture is below 20% and must be stored or transported to the market at 14% of moisture content[3].

When drought condition occurs the corn plant height, leaf area, roots activities, plant biomass, plant flesh and dry weight and stem diameter will be affected significantly. Normally corn leaf ranged between 8-20 leaves which facilitate photosynthesis, transpiration and light absorption but under drought stress leaf size, leaf elongation and leaf number reduced which can limit light interception and decrease photosynthesis due to some leaf fall down or folded[4]. Corn is affected by drought stress through its life cycle, morpho-physiology of corn at both cell, wholes plant levels and reduce anthesis silking interval[5]. Water shortage at vegetative and flowering development stages significantly affect roots morphology, reproductive tissues, biomass production and finally grain yield. Roots length, size, depth and density are the key for drought adaptable on plant as the roots has connection in searching for water and nutrient in soil. The ratio of roots weight to shoot weight is a greater index to show drought resistance because large deep rooted system are able to absorb and extract more water relative to smaller shoots which transpire less and lose less water under drought condition[6]. There are many corn cultivars in Thailand with different yield performance[7] and different to drought stress adaptability but there are few or no studies specifically on the drought adaptable cultivars and the roots traits whereas the root is the primary organ for water and nutrient uptake. Therefore, the aim of this research was to evaluate corn drought adaptability traits, growth, development and yield of drought adaptable corn cultivars under different water stress in greenhouse condition.

MATERIALS AND METHODS

This research was conducted under greenhouse condition at Agronomy Department, Faculty of Agriculture, Kasetsart University, Bangkok during April-September, 2017. The experiment was set up as factorial in Randomized Complete Block Design (RCBD). There were 3 factors in three replications where each replication represents one block. The factors include four level of water potential (soil moisture contents) that is field capacity (W0) 100% SMC-as a control, (W1), 75% SMC-light stress (W2), 50% SMC-moderate stress and (W3), 25% SMC-severe stress, factor 2 was four corn cultivars (SW4452, NS-3, NT6248, NT7328) and factor 3 was different growth stages.

Green house experiment: Polythene bags of 1 m height and 30 cm diameter filled with 80 kg of sieved loam soil sieved in 2 cm^2 sieve then mixed with compost at the rate of 312 kg ha^{-1} equivalent to 129 g/pot. The pot was watered for two days then three seeds were sown in each pot at the spacing of 25×75 cm as recommendation rate. Weeding was done regularly to remove all weeds from the pot by hand. Fourteen days after planting thinning was done by removing one plant and remain with two plants in each pot. During experiment the drought stress was imposed block wise in three stages where block one was imposed at vegetative stage (30 DAP), block two was imposed at flowering stages (60DAP) and block three was imposed at grain formation stages (76 DAP). At the beginning of the experiment all treatment were given the same amount of water to maintain the soil moisture content at the field capacity. Two weeks after germination the pots were drought imposed accordingly 75, 50, 25 and 100% as control. Before imposing the drought all treatments within blocks were subjected to initial soil moisture content of 25% and maintain that block in soil moisture content range between 25-20% for 5 days then start re-watering to maintain the required level of 25, 50, 75% and field capacity (100%) up to harvesting. Then at flowering stage second block was stressed to 25% SMC for 5 days then re-watering and the last block stress was imposed at grain formation stage with the same process. Five days after re-watering since imposed to stress all physiological and roots data were assessed critically to evaluate the cultivars adaptable to the drought and recovery for those three identified stage by comparing with the control.

The fertilizer was applied 3 times, physiological and roots data were collected at every stage during seedling, vegetative, flowering and grain formation. Roots data were collected by randomly removing the selected bag (two plants) in each cultivar for each water level then wash it completely to remove all soil in order to assess the impact of roots length, weight and roots density under drought stress.

Seed germination test: Before starting pot experiment seed germination test was conducted under growth chamber condition. Seed moisture content was measured before germination test by using hot oven dry method[8] and it was found to be 12.2, 10.6, 9.3 and 7.3% for SW4452, NS3, NT6248 and NT7328, respectively. According to O'Reilly and De Atrip[9] initial seed moisture content has effect on seed germination and seedling vigor especially under water deficit condition. For the germination test, seedlings were grown for 21 days where 50 seeds of each cultivar were sown in four SMC levels with 3 replications to compare the seedling vigor of all cultivars under water deficit conditions at the seedling stage.

Physiological parameters collection: Plant height, LAI (Leaf area index) and CGR (Crop growth rate) were determined according to the method of Khalili *et al.*[10] and Simic *et al.*[11] respectively. LAI (Leaf area index) and CGR (Crop growth rate) were calculated by the following formulas:

$$\text{LAI} = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Ground area per plant (cm}^2\text{)}}$$

$$\text{CGR} = \frac{W_2 - W_1}{PT_2 - T_1} g^{-2}/\text{day}$$

Cobs parameters i.e., cob height, cob length, cob weight, 100 seed weight and total production were determined by the method of Khalili *et al.*[10]. The physiological parameters such as plant height, leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR) were evaluated at 20, 40, 60 and 90 DAS (Days after the sowing).

Photosynthetic rate (Pn), Stomata conductance (gs) and transpiration rate was measured using portable photosynthesis system (Li-6400, LiCol, USA) between 1:30 to 3:30 PM with clear day and sunlight.

Data analysis: Data collected from the field was recorded into Microsoft excel then analyzed using Stastix 8.0 for analysis of variance (ANOVA) to determine cultivars which perform well and adapt in drought stress among those four cultivars. Least Significant Difference (LSD) was used to analyze for mean comparison between treatments and their interaction, except flow cytometer data. The ANOVA in two ways analysis was used to compare for significantly different at $p<0.05$. The data analyses were performed using R version 3.2.5 (2016-04-14) copyright (C) 2016 the R Foundation of statistical computing platform: i386-w64-mingw32/i386 (32 bit).

RESULTS

Effect of drought stress at germination stage

Germination period and germination percentage: Under normal condition and moderate stress all cultivars use short period to reach on 50% of germination compared to severe stress. Time (days) used by those cultivars for germination under different water level were 6.5, 5.4, 5.9, 5.3 days under control bloc, 4.8, 4.1, 3.9 and 4.0 days under moderate and 8.2, 7.7, 5.4 and 5.0 days under severe stress respectively for SW4452, Ns-3, NT6248 and NT7328. Drought stress, delayed the germination where the average period for 50% of seed germinated ranged to 5.8, 4.2 and 6.6 days under control, moderate and severe stress, respectively. The percentage rate of seed germinated within cultivars under different stress level were 80.67, 85.33, 69.33 and 79.33 under control, 89.33, 100.00, 100.00, 100.00 under moderate stress and 84.00, 97.33 94.67 and 96.67, respectively for SW4452, Ns-3, NT6248 and NT7328. According to this germination (%), Ns-3 and NT7328 can be classified as best cultivars with highest germination (%) by comparing with other cultivars. Germination (%) were not significantly different between control and moderate stress but under severe stress the germination (%) reduced significantly with a percentage ratio of 93.16, 97.33 and 78.66% for control, moderate and severe stress, respectively (Table 1).

Effect of drought stress on physiological parameters

Number of leaves and plant height: Number of leaves within cultivars was not significantly different with an average of 15.66, 14.00, 16.00 and 16.00, respectively for SW4452, NS-3,NT7328 and NT6248. As crop grown from vegetative to

Table 1: Germination data of four corn cultivars under different water-stress at seedling stage

Cultivars	Max G (%)	GS (%)	GE (%)	T50% (day)	MGT (h)
Control					
SW4452	80.67^{cde}	48.00^{f}	12.16^{c}	6.5b^{c}	122.97^{bc}
NS-3	85.33^{bcd}	60.00^{ef}	17.43^{b}	5.4^{cde}	114.44^{bcde}
NT6248	69.33^{e}	54.00^{ef}	29.35^{a}	5.9^{cd}	100.59^{de}
NT7328	79.33^{de}	62.00^{def}	28.08^{a}	5.3^{cdef}	84.00^{abc}
Mean	93.16	5.6	21.76	5.8	111.33
Moderate stress					
SW4452	89.33^{abcd}	80.00b^{cd}	0.00^{e}	4.8^{def}	114.08^{bcde}
NS-3	100^{a}	100.00^{a}	0.00^{e}	4.1^{ef}	99.90^{de}
NT6248	100^{a}	100.00^{a}	6.67^{d}	3.9^{f}	94.44^{e}
NT7328	100^{a}	98.00^{ab}	0.00^{e}	4.0^{ef}	97.60^{e}
Mean	97.33	94.50	1.66	4.20	101.51
Severe stress					
SW4452	84.00^{bcd}	16.67^{g}	0.00^{e}	8.2^{a}	183.74^{a}
NS-3	97.33^{ab}	17.33^{g}	0.00^{e}	7.7^{ab}	184.60^{a}
NT6248	94.67^{abc}	72.67^{cde}	0.00^{e}	5.4^{cde}	129.30^{b}
NT7328	96.67^{ab}	84.00^{abc}	0.00^{e}	5.0d^{ef}	120.30^{b}
Mean	78.66	47.67	0.00	6.6	154.25
LSD (C*W)	*	*	*	*	*
Grand mean	89.72	66.05	7.80	5.54	124.4
CV	9.50	17.33	17.78	15.39	10.25

Same letter are not significantly different ($p<0.05$) by Fisher's Lsd. T50: Time for 50% germination, Max G (%): Germination percentage GE: Germination energy, GS: Germination speed, MGT: Mean germination time, *Significant at $p<0.05$

Table 2: Physiological parameters of different corn cultivars under different drought stress level

Trt	Var	CGR (g/day)	gs	NL	Pn (µmol m^{-2} sec)	PH (Cm)
Control	SW4452	1.8518^{b}	59.95^{c}	15.66^{a}	5.587^{k}	308.33^{b}
	NS-3	1.2671^{e}	141.31^{a}	14.00^{bc}	22.93^{b}	264.67^{c}
	NT6248	1.2571^{e}	89.78^{b}	16.00^{a}	15.181^{f}	330.00^{a}
	NT7328	1.8513^{b}	37.93^{d}	16.00^{a}	23.353^{a}	288.33^{b}
Mean		1.55	82.24	15.41	16.763	297.83
Light stress	SW4452	1.1027^{f}	16.94^{g}	13.33^{cd}	6.022^{j}	253.33^{c}
	NS-3	1.5169^{cd}	10.04^{n}	15.00^{ab}	21.068^{c}	210.67^{def}
	NT6248	1.9804^{a}	7.77^{o}	12.33^{d}	10.953^{i}	217.00^{de}
	NT7328	1.6081^{c}	12.22^{k}	14.00^{bc}	15.728^{e}	215.00^{de}
Mean		1.550	15.45	13.66	13.443	224.00
Mild stress	SW4452	0.9607^{g}	12.71^{j}	12.33^{d}	11.28^{h}	192.00^{fg}
	NS-3	1.1753^{ef}	10.60^{l}	12.66^{cd}	3.595^{m}	198.67^{efg}
	NT6248	1.5823^{c}	12.67^{j}	12.66^{cd}	19.93^{d}	200.67^{efg}
	NT7328	1.4414^{d}	13.35^{h}	13.33^{cd}	11.49^{g}	207.67^{def}
Mean		1.280	12.33	12.75	11.579	199.75
Severe stress	SW4452	0.7993^{hi}	19.83^{e}	12.00^{d}	4.634^{l}	191.67^{fg}
	NS-3	0.708i	18.44^{f}	12.66^{cd}	1.565^{p}	167.00^{h}
	NT6248	0.9130^{gh}	13.09^{i}	12.00^{d}	2.456^{n}	224.67^{d}
	NT7328	0.878^{gh}	10.45^{m}	13.33^{cd}	2.273^{o}	182.00^{gh}
Mean		0.820	11.74	12.50	2.732	191.33
LSD		*	*	*	*	*
Grand Mean		1.3	30.44	13.58	12.784	228.23
CV		5.7	0.13	6.78	0.240	5.20

Same letter are not significantly different ($p<0.05$) by Fisher's LSdCGR: Crop Growth Rate (g/day), gs: Stomata conductance, NL: Number of Leaf, Pn: Photosynthetic rate (µmol m^{-2} sec), pH: Plant height,*: Significant at ($p<0.05$)

flowering, number of leaves also increased but at grain formation stage, most leaf senesce then abscised which causing lower number of leaves at that stage compared with other stages. Drought stress levels also reduced number of leaves with an average of 15.41, 13.66, 12.75 and 12.5 leaves for control, light, moderate and severe stress, respectively. Plant height also significantly reduced due to drought stress with an average of 297.83, 224.00, 199.75 and 191.33 cm for control, light, moderate and severe stress, respectively (Table 2).

Crop growth rate and photosynthetic rate: Crop growth rate (CGR) increased from seedling, vegetative and become maximum at flowering stage, after it started to be reduced.

Table 3: Effect of different drought stress at different growth stages on flowering period (days)

		Vegetative stage			Flowering stage		
Trt	Cultivars	T(50%) T	T(50%) SI	ASI	T(50%) T	T(50%) SI	ASI
Control	SW4452	3.33^{lmn}	1.13^{l}	2.19^{gh}	3.33^{lmn}	1.67^{jkl}	1.66^{fgh}
	NS-3	2.33^{n}	1.07^{l}	1.26^{efgh}	3.00^{mn}	2.33^{ijk}	0.67^{defg}
	NT6248	8.57^{cdef}	7.33^{ab}	1.24^{efgh}	9.33^{bcd}	6.67^{bc}	2.67^{hi}
	NT7328	2.84^{mn}	3.00^{ghi}	0.15^{bcde}	4.66^{kl}	4.67^{def}	0.00^{cdef}
Mean		4.27	3.13	1.13	5.08	3.83	1.25
Light stress	SW4452	2.83^{mn}	4.52^{ef}	1.69^{bc}	2.65^{mn}	6.62^{bc}	3.64^{a}
	NS-3	7.49^{efgh}	2.63^{hij}	4.86^{jk}	5.61^{ijk}	3.74^{fg}	1.86^{gh}
	NT6248	8.73^{cde}	2.00^{ijkl}	6.73^{lmn}	7.33^{fgh}	1.178^{l}	6.16^{kl}
	NT7328	8.19^{defg}	5.67^{cd}	2.52^{hi}	7.24^{fgh}	0.97^{l}	6.27^{klmn}
Mean		6.81	3.91	2.91	5.71	3.13	2.66
Mild stress	SW4452	3.43^{lmn}	4.29^{ef}	0.86^{bcd}	3.51^{lmn}	5.31^{de}	1.81^{b}
	NS-3	3.90^{lm}	1.33^{kl}	2.57^{hi}	5.55^{ijk}	3.72^{fg}	1.82^{gh}
	NT6248	6.33^{hij}	2.33^{ijk}	4.01^{ij}	9.65^{bc}	1.68^{jkl}	7.96^{gh}
	NT7328	7.32^{fgh}	2.00^{ijkl}	5.32^{jkl}	9.55^{bcd}	1.67^{jkl}	7.88^{mn}
Mean		5.25	2.43	2.76	7.06	3.09	3.96
Severe stress	SW4452	6.89^{ghi}	8.03^{a}	1.13^{bc}	5.378^{jk}	6.51^{bc}	1.13^{bc}
	NS-3	5.56^{ijk}	5.67^{cd}	0.11^{bcde}	6.38^{hij}	1.78^{jkl}	4.58^{jk}
	NT6248	9.59^{bc}	5.00^{de}	4.59^{jk}	10.43^{ab}	3.61^{fgh}	6.83^{lmn}
	NT7328	7.83^{efg}	1.67^{jkl}	6.17^{klm}	11.21^{a}	1.08^{l}	10.13^{o}
Mean		7.47	5.01	2.46	8.35	3.24	5.10
LSD (C*W)	*	*	*	*	*	*	
Grand mean		5.95	3.65	2.31	6.50	3.32	3.24
CV		12.50	18.56	14.78	13.53	17.63	13.59

Same letter are not significantly different at $p<0.05$ by Fishers LSD. *: Significant at $p<0.05$. T(50%)T: Time for 50%tasseling (day), T(50%)SI: Time for 50% silking (day), ASI: Anthesis silking interval (day)

From flowering stage, CGR reduced up to become near to zero at harvesting. Soil moisture level was significantly reduced CGR due to the leaf area and number were reduced by drought stress, then the average of CGR within water level become 1.55, 1.55, 1.28 and 0.82 g/day for control, light, moderate and severe stress, respectively. SW4452 and NT7328 had high CGR than other cultivars with the average of 1.85, 1.26, 1.25 and 1.85 g/day, respectively for SW4452, NS-3, NT6248 and NT7328. Drought stress at vegetative stage had less impact on photosynthetic rate and stomata conductance. Among all those tested cultivars, Ns-3 had high photosynthetic rate and greater stomata conductance. The photosynthetic rate within cultivars were 5.58, 22.93,15.18 and 23.35 μmol m^{-2} sec and stomata conductance were 59.95, 141.31, 89.78 and 37.93, respectively to SW4452, Ns-3, NT6248 and NT7328. Under drought stress the photosynthetic rate and stomata conductance also reduced significantly but the water used efficiency increased. Photosynthetic rate were reduced from 16.76, 13.44, 11.57, 2.73 μmol m^{-2} sec and stomata conductance also become 82.24, 15.45, 12.33 and 11.74 for control, light, moderate and severe stress respectively, which indicated the reduction of gas exchange and finally reduce total photosynthetic rate (Table 2).

Flowering period: Drought stress was imposed in block wise which facilitated to evaluate and compare the effect of drought stress at each stage. On block imposed to drought stress at vegetative stage it took short period to produce reproductive organ while the block subjected to drought stress at flowering stage take long time for 50% tasseling, silking and anthesis silking interval (Table 3).

Time used to produce reproductive organ were 4.27days for tasseling, 3.13 days for silking when drought stress occurred at vegetative stage while drought stress during flowering stage it took 5.08 days for tasseling and 3.83 days for silking. Drought stress also increased time for 50% tasseling with average of 3.13 days at control block and 5.01 days at severe stress on block imposed to drought stress at vegetative stage. When drought occurred at flowering stage, period used for tasseling also increased by comparing to control block with an average of 5.08 days on control block and 8.35 days under severe stresscondition (Table 3).

Number and roots length: Total average of roots length were 120.67, 111.67, 123.33 and 101.47 cm for SW4452, Ns-3, NT6248 and NT7328, respectively. Under severe stress, roots length reduced significantly from 114.28, 105.5, 116.64 and 96.06 cm, respectively for control,

Table 4: Effect drought stress on roots parameters

Trt	Cult	NR	LR (Cm)	RFW (gr)	RDW (gr)
Control	SW4452	16.33[b]	120.67[d]	120.84[a]	21.16[a]
	NS-3	20.33[a]	111.67[ef]	91.47[d]	12.30[bcde]
	NT6248	22.00[a]	123.33[cd]	91.62[d]	11.61[cdef]
	NT7328	17.67[b]	101.47[g]	87.04[e]	13.63[b]
Mean		19.083	114.28	97.74	14.67
Light stress	SW4452	11.33[cd]	94.33[h]	65.50[h]	10.34[fg]
	NS-3	13.33[c]	125.67[bc]	91.33[d]	12.63[bcd]
	NT6248	12.33[c]	110.67[f]	98.00[c]	22.93[a]
	NT7328	12.00[c]	91.33[h]	103.83[b]	13.45[bc]
Mean		12.25	105.5	89.66	14.83
Moderate stress	SW4452	11.66[cd]	94.33[h]	81.50[f]	12.48[bcd]
	NS-3	13.33[c]	151.33[a]	87.14[e]	10.49[efg]
	NT6248	11.667[d]	127.00[b]	75.83[g]	13.63[b]
	NT7328	13.33[c]	93.90[h]	93.40[d]	11.30[def]
Mean		12.50	116.64	84.46	11.97
Severe stress	SW4452	11.66[cd]	110.10[f]	64.10[h]	8.34[h]
	NS-3	13.00[c]	114.00[e]	59.00[i]	6.23[i]
	NT6248	13.33[c]	87.00[i]	64.00[h]	10.92[def]
	NT7328	9.66[d]	73.13[j]	56.47[i]	8.60[gh]
Mean		11.917	96.06	60.89	8.52
LSD (C*W)		*	*	*	*
Grand mean		13.938	108.12	83.19	12.50
CV		9.740	1.72	2.61	9.25

Means followed by the same letter are not significantly different ($p<0.05$) by Fisher's LSd. NR: Number of roots, LR: Length of roots (cm), RFW: Roots fresh weight (gr), RDW: Roots dry weight (gr), *: Significant at $p<0.05$

light, moderate and severe stress. Roots fresh and dry weight was greater on SW4452 with 120.84, 91.47, 91.62 and 87.04 g and dry weight were 21.16, 12.30, 11.61 and 13.63 g, respectively for SW4452, Ns-3, NT6248 and NT7328. The greater number of roots at irrigated block facilitated to increase also the fresh and dry weight at control block followed by light stress and moderate while less roots weight was founded at severe stress. Roots fresh weight within different drought stress level were 97.74, 89.66, 84.46, 60.89 g and roots dry weight were 14.67, 14.83, 11.97 and 8.52 g, respectively for control, light, moderate and severe stress. Average number of roots slightly reduced with the increase of drought stress level and become 19.083, 12.25, 12.5 and 11.91, respectively for control, light, moderate and severe stress (Table 4).

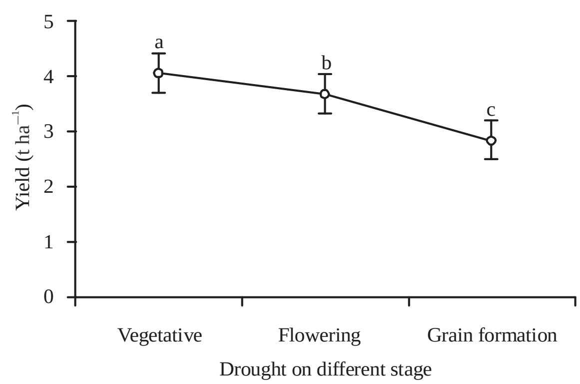

Fig. 1: Effect of drought stress at different corn growth stage on yield production

Effect of drought stress at different growth stage on yield production

Yield production per hectare: The result showed high yield production per plant and per hectare, high mean production (MP) and yield stability (YSI) under block imposed to drought stress at vegetative stage followed by flowering stage while drought at grain formation stage reduce completely the yield production per hectare with a cumulative yield t ha^{-1} ranged to 4.06, 3.69 and 2.85 respectively when drought stress imposed at vegetative, flowering and grain formation stage (Fig. 1). When drought stress level increased the yield production t ha^{-1} also reduced from 6.10, 3.05, 2.76 and 2.23 t, respectively for control, light, moderate and severe stress. Among all those cultivars, NT7328 and SW4452 showed a significantly different within other cultivars and NT6248 showed less yield production by comparing to others with an average yield t ha^{-1} of 6.79, 5.27, 3.66 and 8.68 t ha^{-1} for SW4452, NS-3, NT6248 and NT7328, respectively (Table 5).

Mean production under drought stress: The mean production for those different corn cultivars under control block were 63.67, 49.46, 34.33 and 81.43, respectively for SW4452, NS-3, NT6248 and NT7328 (Table 5).

Table 5: Yield production of different corn cultivars under different drought stress level

Trt	Var	Y/H (t ha^{-1})	MP	SSI	STI
Control	SW4452	6.791^{ab}	63.672^{ab}	0.0000^{a}	1.00^{ab}
	NS-3	5.276^{bc}	49.464^{bcd}	0.0000^{a}	1.000^{ab}
	NT6248	3.662^{cd}	34.339^{cd}	0.0000^{a}	1.000^{ab}
	NT7328	8.686^{a}	81.435^{a}	0.0000^{a}	1.00^{ab}
Mean		6.104	57.220	0	1
Light stress	SW4452	3.320^{d}	36.814^{cd}	0.9664^{a}	0.1848^{bcd}
	NS-3	3.386^{cd}	44.895^{bcd}	0.4031^{a}	0.9255^{ab}
	NT6248	2.508^{d}	32.042^{d}	1.0167^{a}	0.864^{abc}
	NT7328	2.984^{d}	40.717^{cd}	1.000^{a}	0.000^{d}
Mean		3.052	38.610	0.840	0.49
Mild stress	SW4452	3.104^{d}	55.147^{bc}	1.408^{a}	0.623^{abcd}
	NS-3	2.379^{d}	50.255^{bcd}	0.9874^{a}	1.0316^{a}
	NT6248	2.143^{d}	31.683^{d}	2.0324^{a}	1.2097^{a}
	NT7328	3.426^{cd}	46.820^{bcd}	0.9987^{a}	0.0849^{cd}
Mean		2.763	45.97	1.350	0.73
Severe stress	SW4452	1.952^{d}	42.021^{bcd}	0.5919^{a}	0.597^{abcd}
	NS-3	2.66^{d}	36.878^{cd}	0.9660^{a}	0.5084^{abcd}
	NT6248	2.269^{d}	29.122^{d}	0.4311^{a}	0.869^{abc}
	NT7328	2.039^{d}	54.876^{bc}	1.0209^{a}	0.799^{abcd}
Mean		2.230	40.720	0.750	0.690
LSD		*	*	*	*
Grand mean		3.53	45.63	0.73	0.73
CV		57.40	28.65	29.33	68.32

Means followed by the same letter are not significantly different ($p<0.05$) by Fisher's LSd. Y/H: Yield per hectare (t ha^{-1}), MP: Mean production, SSI: Stress susceptible index, STI: Stress tolerance index, *: Significant at ($p<0.05$)

DISCUSSION

This research with aim of evaluating the adaptability of different corn cultivars under drought stress at different stages discovered that, NT7328 and SW4452 cultivars is recommended as the best drought adaptable cultivars since it was able to give better yield production when drought stress occurs at vegetative, flowering and grain formation corn growth stages while NT6248 can be classified as drought vulnerable cultivar by comparing to others used in this research due to low physiological performance and less final yield production per hectare.

Drought stress can delay or completely limit seed germination, reduce plant physiological development and final yield production[12]. The similar result were founded in research done by Bakht[13] and Delachiave and Pinho[14], who found that drought stress which occurred at planting period or at germination period can cause poor seed germination, seed establishment and seedling vigor. Research done by Anjum *et al.*[15] to evaluate the effect of drought stress on corn morphological, physiological and biochemical function found a reduction on number of leaf by drought stress occurred at grain formation more than other stages due to all old leaf get senesces and fall down which can reduce number of leaf, photosynthetic rate, carbohydrate assimilation and finally reduce the final yield production. Aslam *et al.*[16] found that, number of dried leaf and senescence increased rapidly for the corn affected by the drought at grain formation which can reduce the leaf area, number of leaf and photosynthetic rate. The comparable result also was published by Homayouni[17] in research done in green house condition and found the shoots fresh and dry weight, plant height and diameter reduction during irrigation holding at grain formation stage than other corn growth stages. Bhatt and Rao[18] found a leaf senescence and decline in cell enlargement by drought stress which can lead to diminution of plant height and stem size. A common feature of drought stress is a reduction of leaf fresh and dry weight[19], plant height and stem diameter[20] then finally number of leaf and leaf area which can disturb photosynthetic pigment and reduce photosynthetic rate[21,22]. During the crop growth, within 60 days after planting plant canopy was intense by comparing to other growth period which can facilitate to get higher CGR, NAR and photosynthetic rate at that period but when plant scope to maturity from 105-120 days the growth rate reduced and turn up to zero[23-25]. The research done by Sakata[26] found that drought stress at early plant development has less impact on plant activities due to the water demand was less and the plant tissue organ have ability to protect themselves against damaging unless if there is extremely stress, However, they found an increase on time for 50% tasseling, silking and anthesis silking interval when drought occurred at flowering stage. Cultivars with short time of flowering under drought stress may consider as highly adaptable cultivars because it can escape drought stress by completing its life cycle before drought stress occured[26-29]. Barker *et al.*[30] highlight that a water shortage, especially at flowering stage can limit the development of leaf, leaf area, leaf area index and less carbohydrate production which can increase time for tasseling, silking and anthesis silking interval. The research done in green house by Edmeades[31] to study the response of different corn cultivars under drought stress at different growth stages found that drought stress reduce the length, number, fresh and dry weight of roots for drought vulnerable than drought adaptable cultivars. Drought adaptable cultivars overcome with drought stress by directing roots growth in deep of soil then uptake and accumulate dry matter from the shoots to the roots for long survive under stress condition[32-35]. Rafiee *et al.*[36] found that a daily stress at grain formation stage reduce 2.5-5.8% of final yield production by comparing to control block. Khodarahmpour[37] described that by selecting the adaptable cultivars high and significant yield production under control and stress block must be evaluated. High MP, STI in each stage can be consided as most drought adaptable cultivars while low value of stress susceptible index (SSI) are suitable to be selected as best drought adaptable cultivars[38-40]. Traore *et al.*[41] and Rashwan *et al.*[42] reported that number of grain per cobs was different within water level and stage of crop during drought stress where a reduction of soil moisture content reduces the number of grain per plant and final yield production. Roots morphology and roots function must be evaluated particularly as a best factors to strengthen corn under drought stress condition. This study will help the researchers and plant breeder to discover new and high drought adaptable cultivars by starting on discovered adaptable cultivar.

CONCLUSION

NT7328 and SW4452 cultivars were resulted as the best cultivars to give better yield production when drought stress was applied at different developmental stages. In comparison to others, NT6248 cultivar was declared as vulnerable as it resulted a significant decrease in yield and Physiological performance.

SIGNIFICANCE OF STATEMENTS

This study discovered that cultivars with strong roots system can increase high drought adaptability on whatever growth stage drought stress will be occurred. Drought stress at vegetative stage had less impact on final yield production by comparing with other growth stages. This research finding will help the plant breeders for improving drought adaptability and increase farmer yield production.

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