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Selection Criteria Based on Seedling Growth Parameters in Maize Varies Under Normal and Water Stress Conditions

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ABSTRACT

Selection criteria were formulated based on associations and path analysis of seedling traits in 24 S_1 maize populations under normal and water stress conditions. Fresh seedling weight was kept as ensuing variable. The associations and the contributions of growth components varied with the treatments. Highest positive direct effect was exerted by fresh shoot weight followed by fresh root weight and shoot length under normal and dry shoot weight followed by root branches and tissue water contents under drought conditions. Therefore, selection of seedlings for better growth should be performed according to the environments.

Key Words: Maize; S_1 populations; Seedling traits; Drought; Correlation; Path analysis

INTRODUCTION

Maize is one of the leading cereal food crops in Pakistan. It is a rich source of human food, poultry and livestock feed and raw material for industry. In addition to grain crop, maize is also extensively grown as fodder crop for livestock consumption. Drought is an inevitable and recurring feature of agriculture in Pakistan. It has been estimated that about one third of world's potentially arable land suffers from water shortage, and crop yields are often reduced by drought (Kramer, 1980). Maize being sensitive to drought, generally in Pakistan, is grown under irrigated conditions. Water due to shortage of rains has become scarce. Consequently, Pakistan is suffering from acute (80%) water shortage. Limitations on water use are being imposed in every crop, rather cropping patterns are being changed and under such circumstances evolution of high yielding maize varieties tolerant to drought condition is the dire need to cope with the menace of water shortage. Vigorous seedlings provide basis for good crop stand and productivity (Mock & McNeill, 1979; Koscielniak & Dubert, 1985). Therefore, the evaluation of various crops at the seedling stage is an important aspect of crop breeding programme with the objective to evolve drought tolerant varieties.

Correlation and path analysis provide information on the genetic association among various plant traits and their relative contribution to the final seedling growth. Such information will help to ascertain the merits of individual characters as growth promoting traits. There are reports in the literature that extensive rooting system that could explore deeper soil layers for water help in tolerating the drought stress (Mirza, 1956; Bocev, 1963). Maize plants with more roots at seedling stage developed stronger root system, produced more green matter and had higher values for most characters determining the seed yield (Bocev, 1963). Significant varietal differences in root growth and development both under normal and drought conditions exist among various crop plants including maize (Nour & Weibal, 1978; Maiti *et al.,* 1996; Mehdi & Ahsan, 1999) and therefore, could be used as selection criteria for improved drought tolerance in various crops (Clarke, 1987; Gregory, 1989; Mehdi *et al.,* 2001). However, root growth in cultivars capable of avoiding drought through enhanced water uptake is increased (Aggarwal & Sinha, 1983; Dai *et al.,* 1990; Kondo *et al.,* 2000). Nevertheless, reduction in root growth and development in response to drought has also been reported in literature (Shiralipour & West, 1984; Thakur & Rai, 1984; Ramadan *et al.*, 1985). In a biological system, two characters may be associated with each other and such associations may be the product of some pleiotropic effects of a gene, linkage, chromosomal segmental affiliation or due to environmental influences. Correlation analysis figure out the intensity and direction of relationship between the two traits and path coefficient disentangles the total correlation into direct and indirect effects. Present studies were taken up with the idea to have active information about the nature, extent and direction of correlation that would be extended for practical considerations for the evolution of high yielding better quality cultivars under drought conditions.

METERIALS AND METHODS

Studies on various seedling traits and path coefficient analysis in twenty four S_1 maize populations under normal and water stress conditions were conducted in triplicate Completely Randomized Design in the wire-house of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad during the year 2000–2002. Maize germplasm was collected from different research organizations of the country and was sown during spring

2000 in the field. It was allowed to open-pollinate, seed was collected in bulk and a randomly taken sample of it was sown during autumn in the field. The plants were categorized into three groups based on height. The seed obtained from similar looking selfed tall plants was bulked that formed a "tall population". From the remaining plants the better ones were selfed to form S_1 families and the seed obtained from the unselected plants formed an "intercross population".

S_1 families so developed from the collected germplasm were grown and evaluated under drought and normal irrigation conditions using Completely Randomized Design with three repeats. Drought condition was simulated by watering the plants with quantity of water 50% of normal condition. Twelve seeds per S_1 family in a replication were grown in iron trays filled with river sand by keeping row to row and plant to plant distance 5 and 3 cm, respectively. After two weeks data were recorded for fresh seedling weight, fresh root weight, fresh shoot weight, root branching, root length, shoot length, dry root weight, dry shoot weight and water contents under both conditions. Data were subjected to analysis of variance and co-variance (Steel & Torrie, 1980). Path coefficient analysis was worked out using genetic correlation as prescribed by Dewey and Lu (1957) keeping the fresh seedling weight as resultant variable and other traits as causal variable.

RESULTS AND DISCUSSION

Generally, genotypic correlations were higher than phenotypic ones, which reflected the dominant role of the genetic factors compared to environmental ones. Under normal conditions the correlations of fresh root weight, fresh shoot weight, water content and shoot length with fresh seedling weight were important with the magnitude in the decreasing order having positive direction whereas under drought conditions the order of characters was changed, and fresh root weight instead of fresh shoot weight turned up the most important seedling character (Table I). The other important correlations were developed by fresh root weight, fresh shoot weight and water contents with the magnitude in the same order, reflecting that under drought conditions the roots turned up as most important sink, whereas under normal conditions shoot is the most important sink for growth and development. With the selection of types having seedlings possessing good rooting system, high water content and high dry shoot weight, drought tolerant and high yielding types could be evolved.

Fresh shoot weight showed positive and significant correlation with fresh root weight, root length and water contents and negative correlation with dry shoot weight and shoot length at genotypic as well as phenotypic levels. However, under drought conditions fresh shoot weight was positively correlated with fresh root weight, water contents and fresh seedling weight whereas, negatively correlated with root branching, dry shoot weight, dry root weight, shoot length and root length at genotypic level. From Table I, it is clear that under drought conditions fresh shoot weight showed strong positive correlation with fresh root weight and water content. Therefore with the selection of seedlings having higher root weight with higher water contents could help increase fresh shoot weight and eventually fresh seedling weight. Water stress limited not only the size of individual plants but also number of leaves, therefore, ultimately shoot weight of plant was affected under limited water supply. Mehdi and Ahsan (1999) also reported

Table I. Genotypic and phenotypic correlations among various seedling traits of maize under normal and drought conditions

	FSWT	FRWT	RB	DSWT	DRWT	SL	RL	WC	FSDWT
FSWT	1	1.005** 0.275**	-0.175* 0.123	-0.578** 0.066	-0.787** 0.089	-0.090** 0.033*	-1.098** -0.189	1.780** 0.103*	1.044** 0.830**
FRWT	1.255** 0.361**	1	0.347* 0.328	0.628** 0.036	-0.049** 0.101	0.863** 0.332*	-0.282** -0.081	0.847** 0.589**	1.091** 0.760**
RB	0.227 0.176	-0.503* 0.133	1	0.259** 0.141	0.115** 0.101	0.818** 0.375*	0.212** 0.106	0.259** 0.302**	-0.076 0.237
DSWT	-0.342 -0.090	-0.323 -0.101	0.289 0.012	1	-0.302** -0.086	0.624** -0.026*	0.226** -0.182	0.060** -0.244**	-0.392 0.012
DRWT	0.017 0.307	0.373 0.117	-0.328 -0.172	-0.246 0.030	1	0.342** 0.168*	0.072** -0.152	0.454** -0.007**	0.128 0.274
SL	-0.048 -0.005	-0.390 0.257	0.136 0.122	0.371 0.012	-0.579** -0.320	1	-0.065** 0.172	0.685** 0.245**	-0.064 0.139
RL	0.306* 0.320	0.364** 0.192	-0.527** 0.203	0.685** -0.130	-0.220** 0.098	0.633** 0.202	1	0.222** 0.204**	-0.417* 0.322
WC	0.244** 0.240	0.766** 0.255	-0.219* 0.065	-0.339** -0.260	-0.034** -0.337	-0.017** 0.126	0.266** 0.083	1	0.712** 0.310
FSDWT	0.879** 0.254	0.919** 0.853	0.454* 0.333	0.428* 0.066	-0.255 0.029	0.852** 0.434	-0.111 0.008	0.853** 0.437	1

*=Significant ($P \leq 0.05$); ** = Highly significant ($P \leq 0.01$); upper and lower diagonals are for correlation under drought and normal conditions; respectively. Upper value (genotypic correlation); Lower value (phenotypic correlation) FSWT = Fresh shoot weight; FRWT = Fresh root weight; RB = Root branching; DSWT = Dry shoot weight; DRWT = Dry root weight; SL = Shoot length; RL = Root length; WC = Water contents FSDWT= Fresh seedling weight

positive correlation between root weight and shoot weight under stress conditions.

Fresh root weight showed positive genotypic correlation with root branching, dry shoot weight, shoot length, water contents and negative with dry root weight and root length in drought and the situation was totally opposite under normal conditions, where fresh root weight increased. This indicated more dry weight and extensive root branching and water content of plant with increase in water supply under drought because plant try to maintain and store water by branching its roots under unfavorable conditions, under normal conditions due to continuous supply of water no such adaptation was needed. Plants with more root weight at seedling stage subsequently develop stronger rooting system, generate higher fresh root weight and produce higher values for most characters determining the yield. The results indicated that seedlings which show well developed viable rooting system have higher potential to tolerate drought conditions. Bocev (1963) reported that the seedlings showing well developed rooting system also show well developed rooting system at final stage, thus providing evidence that the plant types showing drought tolerance at seedling stage will also show tolerance at later growth stages.

Under drought root branching showed highly significant and positive correlation with root length, shoot length, water content dry root weight and dry shoot weight at genotypic level. The greater the root length the more will be number of branches and ultimately more dry root weight under drought conditions.

Under normal conditions dry shoot weight was positively correlated with shoot length and root length. Under drought conditions dry shoot weight showed significant and positive correlation with shoot length, root length and water content, reflecting an increase of shoot length and root length with the increase in dry shoot weight. Increase in dry shoot weight could be attributed to the growth and buildup of unused carbon compounds which are continuously produced due to photosynthesis and accumulated due to limited usage or are accumulated actively for osmotic adjustment. In present study, the development of positive correlation between dry shoot weight and shoot length under drought conditions partially might be attributed to the seedling osmotic adjustment, which helped the seedlings to continue growth.

Dry root weight developed strong negative correlation with shoot length, root length and water content under normal conditions. The correlation reflects that at enough water supply conditions the development of large rooting system will tend to decrease the shoot length. The development of large rooting system will drive more photosynthates to roots leaving little share for shoot development.

The results indicate that selection for large rooting system under drought conditions is beneficial but under normal conditions it seems not economical for the plants. Dry root weight under drought conditions showed positive correlation, in contrast to normal conditions, with water contents, root length and shoot length. The correlation indicates that under drought conditions high dry root weight would result longer shoots, due to high water absorption, which may be due to osmotic adjustment.

Table II. Direct (diagonal) and indirect effects of various seedling traits under normal condition

Variables	FSWT	FRWT	RB	DSWT	DRWT	SL	RL	WC	r_g
FSWT	0.690	0.685	-0.038	0.011	0.001	-0.015	-0.055	-0.237	1.044
FRWT	0.866	0.546	0.076	0.011	0.004	-0.124	-0.065	-0.215	1.091
RB	0.157	-0.274	-0.152	-0.011	0 .003	0.043	0.094	0.061	-0.076
DSWT	-0.230	-0.176	-0.044	-0.034	0.002	0.118	-0.123	0.095	-0.392
DRWT	0.011	0.204	0.050	0.008	-0.011	-0.184	0.039	0.009	0.127
SL	-0.033	-0.213	-0.020	-0.012	0.006	0.318	-0.113	0.004	-0.064
RL	0.211	0.199	0.080	-0.023	0.002	0.201	-0.179	-0.075	0.417
WC	0.583	0.418	0.033	0.011	0.004	-0.005	-0.047	-0.281	0.712

The bold values are the direct effects. FSWT = Fresh shoot weight, FRWT = Fresh root weight, RB = Root branching, DSWT = Dry shoot weight, DRWT = Dry root weight, SL = Shoot length, RL = Root length, WC = Water contents

Table III. Direct (diagonal) and indirect effects of various seedling traits under drought condition

Variables	FSWT	FRWT	RB	DSWT	DRWT	SL	RL	WC	r_g
FSWT	0.235	0.156	-0.149	-0.507	-0.121	0.091	0.159	1.157	0.879
FRWT	0.237	0.156	0.296	0.551	-0.007	-0.869	0.004	0.550	1.918
RB	0.041	0.054	0.855	0.227	-0.017	-0.824	0.003	0.168	0.454
DSWT	-0.136	0.098	0.222	0.876	-0.046	-0.628	0.003	0.039	0.427
DRWT	-0.185	-0.007	0.099	-0.265	0.153	-0.344	0.001	0.295	-0.255
SL	-0.021	-0.134	0.700	0.547	0.052	-1.007	0.001	0.445	0.852
RL	-0.259	-0.044	0.182	-0.198	0.011	0.066	-0.014	0.145	-0.111
WC	0.420	0.132	0.221	0.052	0.069	-0.689	0.003	0.650	0.853

The bold values are the direct effects. FSWT = Fresh shoot weight, FRWT = Fresh root weight RB = Root branching, DSWT = Dry shoot weight, DRWT = Dry root weight, SL = Shoot length RL = Root length, WC = Water contents

Shoot length under drought conditions showed strong significant positive correlation with water contents obviously the seedlings showing higher water contents will have good growth in form of cell division and cell enlargement giving rise longer shoots. Alkhafa *et al.* (1985) reported that shoot length and root length both decreased as the soil moisture was decreased. Stocker (1962) reported that under drought, the epidermal cells had small size limiting the growth.

Root length showed significant and positive correlation with water content under drought conditions as well as under normal conditions, it indicated the development of roots will be facilitated with good water supply. Withholding water resulted in deeper root penetration which corroborated with the findings of Sharp and Davis (1985) and Mirza (1956).

The highest positive direct effect on fresh seedling weight was exerted by fresh shoot weight (0.690) under normal condition and dry shoot weight (0.876) under drought conditions. Maximum negative direct effect was made by water contents under normal conditions (-0.281) and by shoot length (-1.007) under drought conditions The Tables II and III revealed that high positive direct effect of fresh shoot weight (0.690) on fresh seedling weight under normal conditions but low positive direct effect (0.235) under drought conditions. Further more indirect effect of fresh shoot weight through root branching, shoot length, root length and water contents appeared negative and through fresh root weight, dry shoot weight and dry root weight positive under normal condition. Direct and indirect effect of fresh shoot weight and fresh root weight were more important contributing towards fresh seedling weight having maximum effects under normal conditions. Whereas, under drought condition, water contents and root length were the most important traits indicating maximum positive indirect effect on fresh seedling weight. With increase in water contents in water deficit condition increase in weight of seedling would take place, and vice versa. Elizondo and Blasquez (1977) reported that plant height was significantly reduced with application of drought especially at seedling stage. Similar results were reported by Sandhu and Horton (1977). Malik *et al.* (1979) was of the view that as soil moisture capacity decreased, the root elongation was faster.

Direct and indirect effects of fresh root weight under normal conditions indicated the importance of growth and development of shoot to produce photosynthates and the development of roots to supply water and minerals to the growing shoots for the development of seedling fresh weight. Whereas, under drought conditions the most important were water contents, dry shoot weight and root branching, indicating that plants physiological activities are changed under water deficit conditions. Roots develop more branches to explore large soil profile for water, to develop and strengthen rooting system itself and to absorb more water for continuation of growth. From the study of direct and indirect effect of root branching, it is clear that dry shoot weight and shoot length contributed to fresh shoot weight. Thakur and Rai (1984) reported that water stress decreased the length of shoot and Alam (1985) and Ramadan *et al.* (1985) also reported that shoot elongation during vegetative period was reduced by water stress perhaps due to inefficient transport of nutrients in water limiting condition. Very high positive direct effect of dry shoot weight upon fresh seedling weight under drought could partly be due to the biomass of shoot and partly due to the accumulation of organic and inorganic solutes for osmotic adjustment. Similar results were reported by Alam (1985), Ramadan *et al.* (1985) and Thaukar and Rai (1984).

Dry root weight effected fresh seedling weight indirectly through shoot length under drought and normal conditions. This may be due to adaptation of the plants to retain water under water stress conditions. Ashraf (1989) and Rahman *et al.* (1994) observed that moisture treatment significantly affected the expression of root branching and dry weight of the roots. Under drought conditions, in contrast to normal conditions extremely high negative direct effect of shoot length was observed. Shoot length had high positive indirect effects through root branching, dry shoot weight and water contents under drought. These positive indirect effects not only masked the high negative direct effect of shoot length rather were responsible for the development of a very high positive genetic correlation between shoot length and fresh seedling weight. The results indicated that although shoot length under drought condition had positive correlation with fresh seedling weight yet due to its high negative indirect effect care needs to be taken during selection on the basis of shoot length. The trend in drought is different from that of normal conditions because shoot length has its maximum indirect effect through root branching under drought conditions but negative effect under normal conditions. The reason for this is that in water stress conditions root branches spread to explore water and root system became very strong and supportive by further branching under water deficit conditions and in normal conditions water easily available and roots find water nearby level so no need of extensive branching. Overall shoot growth reduced under drought conditions (Robins & Domingo 1953; Guneyli *et al.*, 1969; Ehlig & Lemert, 1976; Aggarwal & Sinha, 1983; Tisdale & Nelson, 1984; Rahman & Hassaneinn, 1988; Thakur & Rai, 1984; Weerathaworn *et al.*, 1992; Aziz *et al.*, 1993).

It is concluded that maximum direct effect upon fresh seedling weight was exerted by fresh root weight and fresh shoot weight under normal condition, and root branching, dry shoot weight and water contents under drought condition. This is emphasized that selection criteria based on seedling growth parameters in maize varies under normal and water stress conditions. Therefore, selection to improve drought tolerance must be performed under drought conditions only then it will be effective in improving fresh seedling weight which in turn could be related to yield.

REFERENCES

Aggarwal, P.K. and S.K. Sinha, 1983. Relationship between mother shoot and tillers as a criterion of selection for wide or specific adaptability to drought in wheat. *Zacker–Planzenb*, 152: 310–20

Alam, A.N., 1985. Evapotranspiration and yield of corn as related to irrigation timing during silking. *Dissrt. Abst. Int.,* 46: 174–5

Alkhafa, S.K., I.A. Hussain and K.Z. Al–Janabi, 1985. Effect of soil water potential, irrigation method and plant density on cotton root growth under field conditions. *J. Agric. Water Resources,* 4: 31–44

Ashraf, M., 1989. Effect of water stress on maize cultivars during the vegetative stage. *Ann. Arid Zone*, 28: 47–55

Aziz, M.A., E. Abu–Gable, M.A. El–Toni and M. Galal, 1993. Effect of irrigation water, salinity and soil moisture stress on some characters of plant grown in different soil. *Egyptian J. Soil Sci.,* 33: 47–62

Bocev, B.V., 1963. Maize selection at an initial phase of development. *Kukuruzu,* 1: 54

Clarke, J.M., 1987. Use of physiological and morphological traits in breeding programme to improve drought resistance of cereals. *In:* Srivastava, J.P., E. Preeddu, E. Acevedo and S. Verma (eds.) *Drought Tolerance Resistance in Winter Cereals.* John Wiley and Sons, New York

Dai, J.Y., W.L. Gu, X.Y. Shen, B. Zheng, H. Qi and S.F. Cai, 1990. Effect of drought on the development and yield of maize at different growth stages. *J. Shery Agric. Univ.,* 21: 181–5

Dewey, D.R. and K.H. Lu, 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.,* 51: 515–8

Ehlig, C.F. and R.D. Lemert, 1976. Water use and productivity of wheat under five irrigation treatments. *Soil Sci. Soc. American J.,* 40: 750–5

Elizondo, S.A. and F.R. Blasquez, 1977. Effect of soil available water contents during the critical period on three cultivars of wheat. *Monterrey, Nuew Leon, Mexico*, 106–8

Guneyli, E., O.C. Burnside and P.T. Nordqwst, 1969. Influence of seedling characteristics on weed competitive ability of sorghum hybrids and inbred lines. *Crop Sci.,* 9: 713–6

Kondo, M., M.V.R. Murty and D.V. Araqones, 2000. Characteristics of root growth and water uptake from soil in upland rice and maize under water stress. *Soil Sci. Pl. Nut.,* 46: 721–32

Koscielniak, J., and F. Dubert, 1985. Biological indices of productivity of various breeding lines of maize. III. Correlation between simple and final yield of grain and dry matter under natural conditions of vegetative growth. *Acta. Agra. Silvestria Ser. Agra,* 24: 35–48

Kramer. P.J., 1980. Drought stress and the origin of adaptation. *In:* Turner, N.C. and P.J. Kramer (eds.) *Adaptation of Plants to Water and High Temperature Stress*. John Wiley and Sons, New York

Maiti, R.K., L.E.D. Amaya, S.I. Cardana, A.M.O. Oimas, M.De La Rosa–Ibarra, and H. De Leoncastillo, 1996. Genotypic variability in maize cultivars for resistance to drought and salinity at seedling stage. *J. Pl. Physiol.,* 148: 741–4

Malik, R.S., J.S. Dhankar and N.C. Turner, 1979. Influence of soil water deficits on root growth of cotton seedlings. *Plant and Soil.,* 53: 109–55

Mehdi, S.S. and M. Ahsan, 1999. Evaluation of S_1 maize (*Zea mays* L.) families at seedling stage for fodder purposes. *Pakistan J. Biol. Sci.,* 2: 404–5

Mehdi, S.S., N. Ahmad and M. Ahsan, 2001. Evaluation of S_1 maize (*Zea mays* L.) families at seedling stage under drought conditions. *On–Line J. Biol. Sci.,* 1: 4–6

Mirza, O.K., 1956. Relationship of root development to drought resistance of plants. *Indian J. Agron.,* 1: 41–6

Mock, J.J. and M.J. McNeill, 1979. Cold tolerance of maize inbred lines adapted to various latitude in North America. *Crop Sci.,* 19: 239–41

Nour, M.A. and D.E. Weibal, 1978. Evaluation of root characteristics in grain sorghum. *Agron. J.,* 70: 217–8

Rahman, A. and A.M. Hassaneinn, 1988. Interactive effect of soil water content and transpiration (PMA) on some physiological activities in maize plants. *Acta Agronmica Hungarica.,* 37: 19–29

Ramadan. H.A., S.N. Al–Niemi, and T.T. Hamdan, 1985. Water stress, soil type and phosphorus effects on corn and soybean, I. Effect on growth. *Iraqi J. Agric. Sci.,* 3: 137–44

Rahman, H., Z.W. Wicks, T.E. Schumacher and Z.A. Swati, 1994. Synthesis of maize populations based on seedling root indices 1. Response of different cereals of moisture stress. *J. Genet. Br.,* 48: 237–43

Robins, J.S. and C.E. Domingo, 1953. Some effects of server soil moisture deficits at specitic growth stages in corn. *Agron. J.,* 45: 618–21

Sandhu, B.S. and M.L. Horton, 1977. Response of oats to water deficit. II. Growth and yield characteristics. *Agron. J.,* 69: 361–4

Sharp, R.E. and W.J. Davis, 1985. Root growth and water intake by maize plants in drying soil. *J. Bot.,* 36: 1441–56

Shiralipour, A. and S.H. West, 1984. Inhibition of specific protein synthesis in maize seedlings during water stress. *Proc. Soil and Crop Sci. Soc. Florida.,* 43: 102–6

Steel, R.G.D. and J.H. Torrie, 1980. *Principles and Procedures of Statistics: A Biometrical Approach. McGraw Hill Book Co*., New York, USA

Stocker, O., 1962. Physiological and morphological changes in plants due to water deficiency, plant water relationships in arid and semi–arid conditions. *Rev. Res. Proc. Medrid Syrop.,* UNESCO, Paris

Thakur, P.S. and V.K. Rai, 1984. Water stress effect on maize cultivars during early stage of growth. *Indian J. Ecol.,* 11: 92–8

Tisdale, S.L. and W.L. Nelson, 1984. *Soil Fertility and Fertilizer,* (3^{rd} ed.) McMillan Publishing Co., Inc. New York

Weerathaworn, P., A. Soldati and P. Stamp, 1992. Seedling root development of tropical maize cultivars at low water supply. *Angwandta Botanic.,* 66: 93–6

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