THE EFFECTS OF SIMULATED DROUGHT CONDITIONS ON THE GROWTH AND DEVELOPMENT OF VARIOUS CORN VARIETIES (*Zea mays* L.)

PHAWINEE CHOTIKUNTA

SUBMITTED TO THE INSTITUTE OF GRADUATE STUDIES
CENTRAL LUZON STATE UNIVERSITY, MUÑOZ,
NUEVA ECIJA, PHILIPPINES IN PARTIAL
FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF SCIENCE IN CROP SCIENCE
(Agronomy)

OCTOBER 1984

The thesis attached hereto, entitled "THE EFFECTS OF SIMULATED DROUGHT CONDITIONS ON THE GROWTH AND DEVELOPMENT OF VARIOUS CORN VARIETIES (Zea mays L.)", prepared and submitted by MS. PHAWINEE CHOTIKUNTA in partial fulfillment of the requirements for the degree of Master of Science in Crop Science (Agronomy) is hereby accepted.

JOSUE A. IRABAGON
Member, Guidance Committee

10/22/84
Date Signed

DANILO T. ELIGIO
Member, Guidance Committee

10-22-84
Date Signed

APOLONIO V. GUEVARRA
Member, Guidance Committee

Oct. 16, 1984
Date Signed

JULITO B. ALETA
Adviser and Chairman
Guidance Committee

Oct. 19, 1984
Date Signed

Accepted as partial fulfillment of the requirements for the degree of Master of Science in Crop Science (Agronomy)

ROMEO L. SAPLACO
Dean, The Institute of Graduate Studies
Central Luzon State University

10/22/84
Date Signed

BIOGRAPHICAL SKETCH

The author was born on May 19, 1953 in Bangkok, Thailand. She is the third of five children of Mr. Mana Chotikunta and Mrs. Supha Chotikunta.

She finished her elementary education at St. Anthony Convent, Chachoengsao Province in 1968 and her secondary education at St. Paul Convent, Cholburi Province in 1971. She continued her high school at Triem Udom Suksa School (Pre-University School), Bangkok. In 1973, she took up higher education at the Kasetsart University, Bangkok. She graduated with the degree of Bachelor of Science in Agriculture major in Agronomy in 1977.

In August 1977, she was employed as an Agronomist at the Department of Agriculture and was assigned in the Field Crops Division (now Field Crops Research Institute) at the Headquarters in Bangkok.

In 1982, she was awarded a fellowship by the Food and Agriculture Organization of the United Nations (UNDP/FAO) to pursue advance studies leading to Master of Science in Crop Science, major in Agronomy and minor in Grain Science, at the Central Luzon State University, Muñoz, Nueva Ecija, Philippines.

Phawinee Chotikunta

PHAWINEE CHOTIKUNTA

ACKNOWLEDGEMENT

The author wishes to express her sincerest appreciation and deepest gratitude to the members of her Guidance Committee: Prof. Julito B. Aleta, Chairman, Advisory Committee, Dr. Josue A. Irabagon, Prof. Danilo T. Eligio and Prof. Apolonio V. Guevarra for their valuable and unselfish help, kind understanding and constant encouragement throughout the course of her study. She is also indebted to Prof. Crispin G. Olo, the former Chairman of the Advisory Committee, for his valuable comments and suggestions during the conduct of the thesis.

Likewise, she extends her sincere and deep appreciation to Dr. Romeo L. Saplaco, Dr. Juliana B. Dacayo, Dr. Oscar B. Zamora, Dr. Roberto Nartea, Dr. R. P. Robles and Dr. A. A. Alejar for their encouragement and supervision.

The author wishes to express sincere thanks to the Food and Agriculture Organization of the United Nations (UNDP/FAO) through Ms. Irene M. Field, Mr. John P. Snell, Dr. Eduvigis B. Pantastico, Mr. Wilson R. Prattley and Mr. Euan Smith for granting her the fellowship and the Thai Government, for granting her the study leave.

Sincere gratitude due Dr. Arwooth Na Lampang, Dr. Eduvigis B. Pantastico, Dr. Sam-arng Srinilta, Dr. Kasem Sooksathan, Mr. W.E.G. Lovell and Ms. Kingkeo Wongcruawal for their encouragement and recommendations in the pursuance of the author's study.

To Mrs. Ludivina P. Santos, Ms. Erlinda D. Villanueva, Mr. Carlos M. Espina, Mr. Romulos T. Seachon, and staff members of UNDP/FAO Office of the Resident Representative in Philippines for their never ending assistance, valuable comments and suggestions.

To the Crop Science Department, CLSU, for the use of their experiment area and to its staff and labor pool for all their help and companionship during the author's conduct of her thesis.

Deep appreciation is due Dr. Filomena F. Campos, Director of the Research and Development Center, Prof. Teotimo M. Aganon, Mrs. Clarita P. Aganon and staff members of the R & DC for their help and in the use of their facilities.

Sincere gratitude is due Dr. Joselito V. dela Cruz the officer in charge of the Feed Grain Processing Center, CLSU, Engr. Jhun M. Salazar, Jr., Essie Padilla and staff members of the FGPC for their kind assistance, in the use of their facilities and the conducive atmosphere which they provided during the author's study in the university.

To Mr. Raul D. Divina, the officer in charge of the Food Processing Center, CLSU, for allowing the author access to the needed facilities and Ms. Mina Padilla and Ms. Malou Siopongco for their kind assistance and support.

To Dr. Ricardo M. Lantican, Director of the Institute of Plant Breeding, UPLB, Laguna, Dr. Dafrosa del Rosario and Mr. Felicito M. Rodriguez for their guidance and assistance in

chemical analysis and help extended.

The author also extends her thanks to Wilfredo del Rosario, Ellen S. Bernardo and Evangeline T. Eligio for the excellent secretarial work in undertaking the arduous task of typing the manuscript.

Special mention is made to Mr. Pracha Boonsompong for his encouragement and invaluable help in the study.

Moreover, sincere thanks are extended to Mr. Generlito G. Ramos, Dra. Josie L. Caranto, Mrs. Generosa N. Eligio, Mr. Damnern Kongsriprai, Mr. Alberto C. Cela Pay and Mrs. Leonila Ramos for all their help and companionship and for making life in the Philippines a memorable one.

To all her Filipino and Thai friends, for the loving atmosphere they provided during the author's entire stay at at CLSU and UPLB, their contributions would not be forgotten.

Lastly, but not the least, the author wishes to dedicate this study to her loved ones: her parents, brothers, sisters, sisters-in-law, nieces, relatives and teachers for their love, prayers and inspiration.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDIX TABLES

ABSTRACT

PHAWINEE CHOTIKUNTA, Central Luzon State University, Muñoz, Nueva Ecija, October 1984. The Effects of Simulated Drought Conditions on the Growth and Development of Various Corn Varieties (Zea mays L.).

Major Professor : Prof. Julito B. Aleta

The experiment was conducted at the experimental area of the Department of Crop Science, CLSU, from January 5, 1984 to May 30, 1984 to evaluate the physiological and other agronomic characteristics of four corn varieties grown under various osmotic pressures and soil moisture conditions.

Factorial in completely randomized design with three replications was used. Four corn varieties, namely IPB 218, IPB Var. 1, DMR Comp. 2 and UPCA Var. 1, five osmotic pressure levels, 0 bar (control), -5 bars, -10 bars, -15 bars and -20 bars and irrigation treatments, non-stress and stress conditions were used.

The results show that under stress conditions corn varieties IPB 218 and UPCA Var. 1 produced higher leaf free-proline content at all levels of osmotic pressure, while DMR Comp. 2 produced the highest leaf total sugar content among the varieties. Plants

subjected to stress had higher degree of free-proline accumulation as well as total sugar content which increased with increasing levels of osmotic pressure. Based on the result, IPB 218 and UPCA Var. 1 are more resistant to early water stress condition while DMR Comp. 2 and IPB Var. 1 exhibited greater degree of resistance to limiting water conditions at later stages of growth.

All varieties differed significantly in terms of ear leaf area, ear diameter, ear height, days to silking, plant height and 100-kernel weight but no significant variations on ear length, number of kernels per ear and grain yield per plant were noted.

Non-stressed plants had significantly greater ear leaf area, wider and longer ear, higher ear height and plant height values, better production of kernels per ear, higher 100-kernel weight and grain yield per plant than stressed plants.

The imposition of water stress during the germination stage provided a conditioning, i.e., hardening effect, as evident in the increased ability to resist moisture stress imposed at the later stages of growth of the corn plant.

LITERATURE CITED

AHRNS, W. 1924. Weitere Untersuchungen über die Abhängigkeit des gegenseitigen Mengenverhältnisses der Kohlenhydrate im Laubblatt vom Wassergehalt. Botan. Arch. 5:234-259.

BARINOWA, R.A. 1937. The dynamics of the carbohydrate colloid complex as a factor of drought resistance in sugar beet. Izvest. Akad. Nauk S.S.S.R. Ser. Biol. No. 1:255-270.

BARNETT, N.M., and A.W. NAYLOR. 1966. Amino acid and protein metabolism in Bermuda grass during water stress. Plant Physiol. 41:1222-1230.

BATES, L.S., R.P. WALDREN, and I.D. TEARE. 1973. Rapid determination of free proline for water stress studies. Plant and Soil 39:205-207.

BEGG, J.E., and N.C. TURNER. 1976. Crop water deficits. Adv. Agron. 28:161-217.

BLUM, A., and A. EBERCON. 1976. Genotypic responses in sorghum to drought stress. III. Free-proline accumulation and drought resistance. Crop Sci. 16:428-431.

BOGGESS, S.F., and C.R. STEWART. 1976. Plant Physiol. 58:796-797.

BOYER, J.S., and H.G. McPHERSON. 1975. Physiology of water deficits in cereal crops. Adv. Agron. 27:1-23.

CAGAMPANG, G.B., and F.M. RODRIGUEZ. 1980. Methods of analysis for screening crops of appropriate qualities. Institute of Plant Breeding. Bull. No. 2, UP at Los Baños, College, Laguna, Philippines.

CARLSON, P.S. 1980. The Biology of Crop Productivity. Academic Press, New York. 471 p.

CHU, T.M., D. ASPINALL, and L.G. PALEG. 1974. Aust. J. Plant Physiol. 1:87-97.

CLASSEN, M.M., and R.H. SHAW. 1970. Water deficit effects on corn. II. Grain components. Agron. J. 62:652-655.

CLEMENTS, H.F. 1937. Studies in drought resistance of the soy bean. Research Studies State Coll. Washington 5(1):1-16.

_____. 1937a. Studies in the drought resistance of the sunflower and potato. Botan. Dept. State Coll. Washington Contrib. No. 59:81-98.

CRAFTS, A.S. 1968. Water deficits and physiological processes. In "Water Deficits and Plant Growth" (T.T. Kozlowski, ed.), Vol. II, Chapter 3, pp. 85-124. Academic Press, New York.

DAR, W.D. 1980. Response of white potato (Solanum tuberosum L.) to moisture stress. Unpublished Ph.D. dissertation, U.P. at Los Baños, College, Laguna, Philippines.

DATA, R.S. 1976. Physiology of wilting among leafy vegetables. Unpublished M.S. Thesis, U.P. at Los Baños, College, Laguna, Philippines.

DENMEAD, O.T., and R.H. SHAW. 1960. The effects of soil moisture stress at different stages of growth on the development and yield of corn. Agron. J. 52:272-274.

DOWNEY, L.A. 1971. Water use by maize at three plant densities. Exp. Agric. 7:161-169.

EATON, F.M., and D.R. ERGLE. 1948. Carbohydrate accumulation in the cotton plants at low moisture levels. Plant Physiol. 23:169-187.

EVANS, W.F., and F.C. STICKLER. 1961. Grain sorghum seed germination under moisture and temperature stresses. Agron. J. 53:369-372.

FISCHER, K.S., E.C. JOHNSON, and G.O. EDMEADES. 1982. Breeding and selection for drought resistance in tropical maize. In "Drought Resistance in Crops with Emphasis on Rice" IRRI, Philippines pp. 377-396.

GATES, C.T. 1968. Water Deficits and Plant Growth (T. T. Kozlowski, ed.) Vol. II, pp. 135-190. Academic Press, New York.

GRANDFIELD, C.O. 1943. Food researves and their translocation to the crown buds as related to cold and drought resistance in alfalfa. J. Agr. Research 67:33-47.

HANSON, A.D., C.E. NELSEN, and E.H. EVERSON. 1977. Evaluation of free-proline accumulation as an index of drought resistance using two contrasting barley cultivars. Crop Sci. 17:720-726.

HARTMAN, P.E., and S.R. SUSKIND. 1965. Gene Action. New York. Prentice Hall Inc. 158 p.

HELMERICK, R.H., and R.P. PFEIFER. 1954. Differential varietal responses of winter wheat germination and early growth to controlled limited moisture conditions. Agron. J. 46:560-565.

HENCKEL, P.A. 1964. Physiology of plants under drought. Annu. Rev. Plant Physiol. 15:363-386.

HENRICI, M. 1945. The effect of wilting on the direct assimilates of lucerne and other fodder plants. S. African J. Sci. 41:204-212.

_____. 1946. Effect of excessive water loss and wilting on the life of plants. Union S. Africa Dept. Agr. and Forestry Sci. Bull. 256:1-22.

HERRERO, M.P., and R.R. JOHNSON. 1980. High temperature stress and pollen viability of maize. Crop Sci. 20:796-800.

_____. 1981. Drought stress and its effects on maize reproductive systems. Crop. Sci. 21:105-109.

HORN, T. 1923. Das gegenseitige Mengenverhältnis der Kohlenhydrate im Laubblatt in seiner Abhängigkeit vom Wassergehalt. Botan. Arch. 3:137-173.

HSIAO, T.C. 1973. Plant responses to water stress. Annu. Rev. Plant Physiol. 24:519-570.

ILJIN, W.S. 1927. Über die Austrocknungsfähigkeit des lebenden Protoplasmas der vegetativen Pflanzenzellen. Jahrb. wiss. Botan. 66:947.964.

_____. 1929. Standortsfeuchtigkeit und der Zuckergehalt in den Pflanzen. Planta 7:59-71.

_____. 1930. Der Einfluss des Welkens auf den Ab-und Aufbau der Stärke in der Pflanze. Planta 10:170-184.

IRRI (International Rice Research Institute). 1976. Annual report for 1975. Los Baños, Philippines. pp. 154-157.

JULANDER, O. 1945. Drought resistance in range and pasture grasses. Plant Physiol. 20:573-599.

KEMBLE, A.R., and H.T. McPHERSON. 1954. Liberation of amino acids in perennial rye grass during wilting. Biochem. J. 58:46-49.

KIESSELBACH, T.A. 1950. Progressive development and seasonal variations of the corn crop. Nebraska Agric. Exp. Stn. Bull. 166.

KISSELEW, N.N. 1928. Der temperatureinfluss auf die stärkehydrolyse in Mesophyll-und Schliesszellen. Planta 6:135-161.

KNIPE, D., and C.H. HERBEL. 1960. The effects of limited moisture on germination and initial growth of six grass species. J. Range Manage. 13:297-302.

KOZLOWSKI, T.T., (ed.). 1972. Water Deficits and Plant Growth, Vol. III, Academic Press, New York. 368 p.

KRAMER, P.J. 1969. Plant and Soil Water Relationships: A modern synthesis. New Delhi. TMH Edition. 482 p.

KRANTZ, B.A. 1949. Fertilize corn for higher yields. North Carolina State College Bull. No. 366.

LARSON, C.A., F.G. VIETS, and R.W. LEAMER. 1950. Field corn production on the Umatilla Irrigation Project. Oregon State College Station Bull. 480.

LAWLOR, D.W. 1970. Absorption of polyethylene glycol by plant and their effects on plant growth. New Phytol 69:501-503.

LEVITT, J. 1956. The Hardiness of Plants. Academic Press, New York. 278 p.

_____. 1972. Responses of Plants to Environmental Stresses. Academic Press, New York. 697 p.

LUNDEGÅRDH, H. 1914. Einige Bedingungen der Bildung und Auflösung der Stärke. Jahrb. wiss. Botan. 53:421-463.

MAGNESS, J.R., L.O. REGEIMBAL, and E.S. DEGMAN. 1932. Accumulation of carbohydrates in apple foliage, bark and wood as influenced by moisture supply. Proc. Am. Soc. Hort. Sci. 29:246-252.

MANOHAR, M.S. 1968. Effect of "osmotic" systems on germination of peas (Pisum sativum L.). Planta (Berl.) 71:81-86.

MAY, L.H., and F.L. MILTHORPE. 1962. Drought resistance of crop plants. Field Crop Abstr. 15(3):171-179.

MAYER, A.M., and A. POLJAKOFF-MAYBER. 1975. "The Germination of Seeds". Pergamon Press, Oxford. 192 p.

McCREADY, R.M., J. GUGGOLZ, V. SILVIERA, and H.S. OWENS. 1950. Determination of starch and amylose in vegetables. Anal. Chem. 22:1156-1158.

MICHEL, B.E. 1971. Further comparisons between carbowax 6000 and mannitol as suppresants of cucumber hypocotyl elongation. Plant Physiol. 48:513-516.

_____, and M.R. KAUFMAN. 1973. The osmotic potential of polyethylene glycol 6000. Plant Physiol. 51:914-916.

MILLER, E.C. 1939. A physiological study of the winter wheat plant in different stages of its development. Kansas Agr. Expt. Sta. Tech. Bull. 47.

MOLISCH, H. 1921. Über den Einfluss der Transpiration auf das Verschwinden der stärke in den Blättern. Ber. deut. botan. Ges. 39:339-344.

MONGELARD, J.C., and L.G. NICKELL. 1971. Sugarcane plant in the soil-plant-atmosphere continuum. ISSCT Proceedings 14:827-840.

NEGER, F.W. 1915. Die Stärke-ökonomie der grünen Pflanze. Naturw. Z. Forstu. Landwirtsch. 13:1.

NIX, H.A. 1975. The Australia: climate and its effects on grain yield and quality. In "Australian Field Crops. Wheat and other Temperate Cereals". (Eds. A. Lazenby and E.M. Matheson). Vol. I, pp. 183-226. (Angus and Robertson: Sydney).

_____, and E.A. FITZPATRICK. 1969. An index of crop water stress related to wheat and sorghum yields. Agric. Meteorol. 6:321-337.

PÁLFI, G. 1969. Determination of irrigation requirement and the selection of drought tolerant plant varieties by means of a new method (Isatin paper indicator method). Noventermetes 18:25.

_____. 1970. Changes in the amino acid content of maize, sunflower, pea and pepper plants in response to drought. Hort. Abst. 40(1):138.

_____, and J. JUHÁSZ. 1971. The theoretical basis and practical application of a new method of selection for determining water deficiency in plants. Plant and Soil 34:503-507.

_____, E. KÖVES, M. BITO, and R. SEBESTYÉN. 1974. Phyton 32:121-127.

PARMAR, M.T., and R.P. MOORE. 1965. Effects of simulated drought by polyethylene glycol solutions on corn (Zea mays L.) germination and seedling development. Agron. J. 58:391-392.

PASSIOURA, J.B. 1977. Grain yield, harvest index and water use of wheat. J. Aust. Inst. Agric. Sci. 43:117-120.

PIERRE, W.H., D. KIRKHAM, J. PESEK, and R. SHAW, (eds.). 1967. Plant Environment and Efficient Water Use. Am. Soc. Agron. and Soil Sci. Soc. Am., Madison, Wisconsin, 295 p.

RAO, J.T. 1960. Xeromorphic adaptations in sugarcane for resistance to drought. ISSCT Proceedings 7:82-89.

RAO, A.S., and H.S. NAINAWATEE. 1980. Water-stress associated proline accumulation in wheat seedlings. Haryana agric. Univ. J. Res., Vol. X, No. 3, pp. 365-368.

RASCO, E.T. Jr. 1974. The effect of hardening on drought resistance and free-proline content of Lycopersicum esculentum Mill. Unpublished M.S. Thesis, U.P. at Los Baños, College, Laguna, Philippines.

RICHARDS, R.A. 1983. Manipulation of leaf area and its effect on grain yield in droughted wheat. Aust. J. Agric. Res. 34:23-31.

ROSA, J.T. 1921. Investigation on the hardening process in vegetable plants. Missouri Agr. Expt. Sta. Research Bull. 48.

ROUTLEG, D.G. 1966. Proline accumulation in wilted ladino clover leaves. Crop Sci. 6:358-361.

SALTER, P.J., and J.E. GOODE. 1967. Crop Responses to Water at Different Stages of Growth. Commonw. Agr. Bur., Farnham Royal, Bucks, England.

SCHNEIDER, G.W., and N.F. CHILDERS. 1941. Influence of soil moisture on photosynthesis, respiration, and transpiration of apple leaves. Plant Physiol. 16:565-583.

SCHOBERT, B. 1977. J. Theor. Biol. 68:17-26.

SEIF, E., and D.G. PEDERSON. 1978. Effect of rainfall on the grain yield of spring wheat, with an application to the analysis of adaptation. Aust. J. Agric. Res. 29:1107-1115.

SHEORAN, I.S., M.I. KHAN, and O.P. GARG. 1980. Rapid technique for screening the barley (Hordeum vulgare L.) varieties for their relative drought tolerance. Haryana agric. Univ. J. Res., Vol. X., No. 3, pp. 369-373.

SINGH, T.N., D. ASPINALL, and L.G. PALEG. 1972. Proline accumulation and varietal adaptability to drought in barley: A potential metabolic measure of drought resistance. Nature New Biol. 236:188-190.

_____. 1973a. Stress metabolism. I. Nitrogen metabolism and growth in the barley plant during water stress. Aust. J. Biol. Sci. 26:45-56.

_____, and S.F. BOGGESS. 1973b. Aust. J. Biol. Sci. 26:57-63.

_____. 1973c. Stress metabolism III. Variations in responses to water deficit in Barley plant. Aust. J. Biol. Sci. 26:65-76.

_____. 1973d. Aust. J. Biol. Sci. 26:77-86.

SINGLETON, H.P., et al. 1950. Soil, water and crop management investigations in the Columbia Basin Project. State College of Washington Bull. 520.

SINHA, S.K., and V. RAJGOPAL. 1976. Effect of moisture stress on proline accumulation in sorghum and wheat. In "Nitrogen Assimilation and Crop Productivity". Sen, S. P., Abrol, Y. P. and S. K. Sinha, (eds.), pp. 158-163. Associated Publishing Company, New Delhi, India.

SLATYER, R.O. 1967. Plant-water Relationships. Academic Press, New York.

_____. 1969. Physiological significance of internal water relations to crop yield. In "Physiological Aspects of Crop Yield" (J. D. Eastin, ed.), pp. 53-79. Amer. Soc. Agron. and Crop Sci. Soc. Amer., Madison, Wisconsin.

SLAVIK, B. 1965. The influence of decreasing hydration level on photosynthetic rate in the thalli of the hepatic Conocephallum conicum. In "Water Stress in Plants" (B. Slavik, ed.), Proc. Symp. Prague, 1963. p. 195. Czech. Acad. Sci., Prague.

STEWART, C.R. 1972. Plant Physiol. 50:679-681.

_____, C.J. MORRIS, and J.F. THOMPSON. 1966. Changes in amino acid content of excised leaves during incubation. II. Role of sugar in the accumulation of proline in wilted leaves. Physiol. 41(10): 1585-1590.

_____, and A.D. HANSON. 1980. Proline accumulation as a metabolic response to water stress. In N.C. Turner and P.J. Kramer, (eds.), "Adaptation of plants to Water stress", pp. 173-190. Wiley Interscience, New York.

SULLIVAN, C.Y., and J.D. EASTIN. 1974. Plant physiological responses to water stress. Agric. Meteorol. 14:113-127.

THOMPSON, J.F., C.R. STEWART, and C.J. MORRIS. 1966. Changes in amino acid content of excised leaves during incubation. I. The effect of water content of the leaves and atmospheric oxygen level. Plant Physiol. 41:1578-1584.

TULLY, R.E., A.D. HANSON, and C.E. NELSEN. 1979. Plant Physiol. 63:518-523.

TUMANOV, I.I. 1930. Welken und Dürreresistenz. Arch. Pflanzenbau 3:389-419.

TURNER, N.C., and J.E. BEGG. 1978. Plant Relations in Pastures (J.R. Wilson, ed.), pp. 50-66. Melbourne: CSIRO.

UHVITS, R. 1946. Effects of osmotic pressure on water absorption and germination of alfalfa seeds. Amer. J. Bot. 33:278-285.

VAN DILLEWIJN, C. 1952. Botany of Sugarcane. Waltham, Mass., USA., The Chronica Botanica Co. : Book Dept. 371 p.

VASSILIEV, I.M., and M.G. VASSILIEV. 1936. Changes in carbohydrate content of wheat plants during the process of hardening for drought resistance. Plant Physiol. 11:115-125.

WALDREN, R.P. and I.D. TEARE. 1974. Free-proline accumulation in drought-stressed plant under laboratory conditions. Plant and Soil 40:689-692.

WILLARD, C.J. 1922. Root reserves of alfalfa with special reference to time of cutting on yield. J. Am. Soc. Agron. 22:595-602.

YOSHIDA, S., D.A. FORNO, J.H. COCK, and K.A. GOMEZ. 1972. Laboratory manual for physiological studies of rice. Second ed. IRRI, Philippines pp. 36-37.

YOUNIS, M.A., F.C. STICKLER, and E.L. SORENSON. 1963. Reactions of seven alfalfa varieties under simulated moisture stresses in the seedling stage. Agron. J. 55:177-182.

TURNER, N.C., and J.E. BEGG. 1978. Plant Relations in Pastures (J.R. Wilson, ed.), pp. 50-66. Melbourne: CSIRO.

UHVITS, R. 1946. Effects of osmotic pressure on water absorption and germination of alfalfa seeds. Amer. J. Bot. 33:278-285.

VAN DILLEWIJN, C. 1952. Botany of Sugarcane. Waltham, Mass., USA., The Chronica Botanica Co. : Book Dept. 371 p.

VASSILIEV, I.M., and M.G. VASSILIEV. 1936. Changes in carbohydrate content of wheat plants during the process of hardening for drought resistance. Plant Physiol. 11:115-125.

WALDREN, R.P. and I.D. TEARE. 1974. Free-proline accumulation in drought-stressed plant under laboratory conditions. Plant and Soil 40:689-692.

WILLARD, C.J. 1922. Root reserves of alfalfa with special reference to time of cutting on yield. J. Am. Soc. Agron. 22:595-602.

YOSHIDA, S., D.A. FORNO, J.H. COCK, and K.A. GOMEZ. 1972. Laboratory manual for physiological studies of rice. Second ed. IRRI, Philippines pp. 36-37.

YOUNIS, M.A., F.C. STICKLER, and E.L. SORENSON. 1963. Reactions of seven alfalfa varieties under simulated moisture stresses in the seedling stage. Agron. J. 55:177-182.