INNOVATIVE TECHNIQUES AND HYPOTHESES DEVELOPED FOR PLANT AND CROP IMPROVEMENT

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ABSTRACT

Although significant advances have been directed in research in plant and crop science but the technologies adopted are complicated and costly. Therefore there is a necessity of the development of simple and low cost technology for understanding basic sciences and its applications in plant and crop sciences. The present papers makes a synthesis of research undertaken by R.K. Maiti and his team on the development of simple low cost technology in various fields of crops and plant sciences.

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INTRODUCTION

It is evident to state that significant research advances have been achieved in various fields of plant, plant and crop sciences both on basic and applied aspects. In many cases sophisticated advance technologies are used to discover new findings but it is highly expensive and beyond the reach of developing countries. Therefore, there is a necessity to develop low cost technology which may be used effectively to screen and select plant and crop species for better performance for example for tolerance to biotic and abiotic stresses and understand their basic mechanism. During the span of about 45 years of research some simple low cost techniques that were developed for effective utilization in plant and crop improvement are briefly reviewed in the present attempt. Most of these innovative techniques are published in various reputed International and National Journals and a few remain unpublished.

Research advances in development of techniques and hypotheses

Fibre crops

During 9 years stay in Ute research Institute research has been undertaken on botany and anatomy of few bas fibre crops such as Jute (*Corchorus olitorius, Corchorus capsularis*), Kenaf, (*Hibiscus cannabinus, Hibiscus sabdariffa*), Ramie (*Boehmeria nivea*), flax (*Linum usitatissimum),* Agave (*Agave sisalana*) and few other species. It is observed that there exists a large variability in fibre bundle structures present in the stem of various bast fibre crops. We predicted that these variabilities among different fibre crops could be related to the quality as well as yield of the fibre crops. For example a low cross sectional area of the fibre bundle could be related to fibre fineness. Length/breadth of the fibre cells is related to fibre bundle strength in jute and other bast fibres. Similarly the cross sectional area of fibre filament in ramie could be related to fineness. On the other hand the number of fibre bundles and layer of fibre bundles in cross section of a stem could be related to fibre yield. This simple technique is being utilized by the breeders in Central Crop Research Institutes on Jute and Allied fibres (ICAR) in mass scale screening of jute and kenaf and ramie. Further, on the basis of these the genetics of fibre quality and yield are being investigated with reasonable success.

Sorghum

During 10 years as Plant Physiologist in ICRISAT various novel techniques in various aspects of sorghum and pearl millet were developed.

Seedling vigour: A simple visual scoring technique was developed on seedling vigour both in sorghum and pearl millet (1= very high vigour, 5- poor seedling vigour). There exists a large variability in seedling vigour scores among sorghum and pearl millet genotypes. This technique is being utilized in mass scale screening sorghum and pearl millet cultivars by crop breeders. In sorghum the genotypes with high seedling vigour are found to have greater capacity in emergence from deeper depth of plantings and are drought resistant at the seedling stage. This is found to be very effective technique in screening of crop genotypes in breeding programmes for various abiotic stresses and for improved yields.

Drought resistance at the seedling stage: Simple techniques were used in screening sorghum genotypes for drought resistance at the seedling stage in pot culture under limited water supply. These could identify the presence of large variability among sorghum cultivars for drought resistance at the seedling stage. This is found to be effective in breeding programme for selecting genotypes for seedling drought resistance.

Depth of planting

It is assessed that there exist large variability in seedling emergence of sorghum for emergence from deeper depth of planting and it is associated closely with the variability of mesocotyle elongation. Genotypes having high mesocotyle elongation are found to show greater emergence from deeper depth of planting. This is an innovative technique in screening cultivars for seedling emergence from deeper depth of soil.

Adaptation to dry sowing

In semiarid regions of India and Africa farmers prepare field before the advent of rains and sow seeds of sorghum. After getting first rain shower the seeds germinate but may dry up if further rain comes late. Therefore, there is a necessity to select genotypes which have a capacity to regerminate and grow. A technique was developed sorghum genotypes. The seeds of sorghum genotypes were kept for germination in petriplates and were allowed to imbibe water for a few hours so that the sequence of metabolic events required for initiation of normal germination process are activated. These seeds were then removed from petriplates and were dried at room temperatures for seven days and later sown in pots. It is observed that some genotypes have capacity to regrowth even after drying. This could be an effective technique in screening crop cultivars for adaptation to dry sowing. This needs to be confirmed.

Glossy sorghum Simple glossy traits at the seedling stage in sorghum were identified against the sorghum shoot fly. Sorghum shoot fly (*Atherigona soccata*) is a serious insect pest affecting drastically sorghum productivity in tropical climates. They lay eggs on the leaf surface and the larva migrate upwards crawling over leaf surface and finally reach the shoot meristem damaging it and stop further growth leading to the production of several unproductive tillers.

Sorghum germplasm can be distinguished into two classes, glossy having light green and shining leaf surface at the seedling stage with erect and narrow leaves compared to the non-glossy lines having deep green, broad and drooping leaves. It has been further identified that glossy lines contain non-glandular trichomes varying again among genotypes, while non-glossy lines contain bicellular glandular trichomes. It has been confirmed that glossy sorghum with high density of non-glandular trichomes are tolerant to shootfly (*Atherigona soccata*). Trichomes offer barriers in the migration of shootfly larva to the shoot apical meristem. Out of 1800 sorghum genotypes 500 glossy lines were selected which showed tolerance to shootfly. The tolerance to shoot fly varied among the lines with reference to the density of the trichomes in the glossy lines. This technique was found to be very effective in screening sorghum germplasm and selecting genotypes for tolerance to shootfly at the seedling stage. Further, researches have documented that glossy sorghum genotypes are tolerant to drought and salinity at the seedling stage. This is really highly innovative technique.

Resistance to Striga, a root parasite

Striga is an obnoxious root parasite affecting sorghum productivity drastically. During screening sorghum genotypes for resistance it has been detected through anatomy of the infected root that the sorghum genotypes resistant to Striga produce a thick band of sclerenchyma below the endodermis offering as a strong barrier for the haustoria penetrate to the vascular bundle and produce some chemical exudant at this point. The paper published in Annals of Botany have been cited more than 150 times.

Pearl millet Research has been undertaken for adaptation of tropical pearl millet in semiarid and highlands of Mexico. It has been confirmed with various studies that pearl millet is well adapted in Mexico and produce higher productivity both for forage and grains. The large difference between day and night temperature and greater day length up to 16 hours is considered to contribute to higher forage and grain yield of pearl millet in Mexico compared to the same cultivars grown in India where there exists a little difference in day and night temperature. This large difference in temperatures of both day and night with a high day temperature and also due to short day length leads to higher photorespiration. In Mexico even if the day temperature is high but night temperature is much lower, thereby leading low photorespiration and high photosynthate assimilation in longer day length. The greater day length and lower night temperature contribute to higher grain yield compared to those grown in India where the temperature both in day and night is higher and day length is shorter.

Novel techniques to identify and develop abiotic stress tolerance in crops

Although it is well known that crops germplasm are the sources of resistance to biotic and abiotic stresses, but resistance is negatively correlated with yield. Therefore, there is a necessity to evaluate pipeline varieties or hybrids for the tolerance using the novel technique and their conformation in the field and thereby to maintain optimum yield under sustainable agriculture. A few simple, cheap but efficient techniques for screening pipe line varieties and hybrids for tolerance to few abiotic stresses such as salinity, drought, heat stress, flooding etc., have been developed in the laboratory, polyhouse and finally the selected genotypes have been tested in the field and confirmed by the breeders revealing the transfer of technology from the lab to the land. The techniques have been well accepted by the breeders useful in mass scale screening.

Semi-Hydroponic Technique for selection of salinity tolerance

A novel Semi hydroponic technique was developed for the selection of salinity tolerant crop cultivars of both field and vegetable crops from pipe line hybrids/parents. In this technique the seeds were sown at a depth of 2 cm in a plastic pot (height 13 cm, upper diameter 14 cm, lower diameter 12 cm) filled with cocoa peat and then applying water or required saline concentration up to two thirds of the pot height (about 70 mm), where the seeds received water by capillarity. The solution, either water or saline was applied only once up to the termination of the experiment (20 days after sowing). To protect seeds from fungal attack, seeds were treated with thiram solution (5 %) for 5 minutes before sowing. Twenty seeds were sown in each pot under control (distilled water) along with 0.2 M NaCl only to confirm high salinity tolerance. Each of the treatments was replicated thrice for all genotypes. This technique simulates a semi-hydroponic system where the upper layers of cocoa peat medium receive water/or saline solution only by capillary movement, while the roots are immersed in saturated lower coco peat medium. Observations were recorded for the 20-days-old seedlings. Some growth criteria such as on average emergence percentage, shoot length (cm), root length (cm) as well as dry weight were recorded on the 15th day for four replicas of seedlings. This technique is highly efficient, repeatable and inexpensive in selecting crop cultivars.

High Seedling Emergence (%), and Profuse adventitious root production was observed in salinity tolerant cereal cultivars and hybrids of rice, maize. In general with an increase in salinity there was an increase in root elongation/increase in number of lateral roots which function in osmotic adjustment. Crop cultivars selected are well confirmed by the breeders in saline prone areas showing the transfer of technology from lab to the land and vice-versa.

Drought tolerance

About one third of arable lands in the world are affected by drought which is increasing constantly. A simple technique has been adopted to screen pipe line crop cultivars exposed to different levels of drought cycle depending on the crop species such as cotton, sunflower, maize, pearl millet, wheat, castor, okra etc. for drought resistance showing genotypic variability both at the seedling and vegetative growth stage. Few cultivars have been selected of each species for drought tolerance and confirmed their efficiency under drought prone areas. Cultivars resistant to drought produced robust root systems and more number of inclined lateral roots at deeper levels. Roots played an important role for adaptation to salinity and drought. Some morpho-anatomical traits were found to be related to drought tolerance. In general drought tolerant cultivars possess profuse trichomes, thick cuticle, compactly arranged palisade cells, strong in the leaves, and thick collenchymas in the petiole. In a study in the case of cotton mass scale screening of about 100 pipe line genotypes of cotton were screened on the basis of these leaf traits and 16 genotypes were short listed about 16 genotypes having adaptive traits. To my utter surprise, these genotypes were found to be well adapted in drought prone areas. This is a classical example of the application of botany in agriculture. Therefore, this can be used in mass scale screening of cotton cultivars for drought tolerance which may be confirmed in further studies in different dicots.

Heat and cold tolerance

The viability of pollen grains of the crops exposed to high temperature of (> 40°C) can be judged with 3% potassium iodide. Staining pollens with 3% potassium iodide of several crop species such as sunflower, maize, pearl millet cultivars grown in hot summer showed that viable pollens of crop cultivars tolerant to heat stress took deep stain.

Screening for Flooding Tolerance

Seedlings were grown normally up to 30 days. After 30 days continuous flooding stress for 10 days were given (stems were submerged up to 4 cm). Experiment was terminated after 40 days and observed percentage of seedling survival, shoot length, and tap root length, number of lateral roots and number of newly formed roots on the submerged portion of stem. In flooding susceptible hybrids, growth rate was drastically reduced and survival of seedling was less compared to tolerant hybrids. Flooding tolerant hybrids showing the formation of roots on the submerged portion of the stem (equal to the water level) under flooding condition and absorb oxygen from its environment. This is an escape mechanism in most of the hydrophytic plant communities.

Specific examples

Cotton

Research has been directed to evaluate Bt cotton hybrids for salinity and drought using a long cost technology to be described in the later part of this article. There existed a large variability among cotton hybrids for tolerance to salinity, drought and flooding. The hybrids selected for salinity and drought were found to be well adapted with reasonable yield in saline and drought prone areas. Salt tolerant cultivars produced greater root elongation and higher root number with increasing salinity functioning adjustment to saline condition compared to the susceptible ones. On the other hand drought tolerant cotton hybrids produced deeper root system compared to the susceptible ones. Therefore, root responses predict the responses of crop cultivars to salt and drought resistance.

Other Field and vegetable crops

Using low cost technology used in cotton, different cereal crops such as pearl millet, maize, rice, wheat, sunflower, castor etc., showing high genotypic variability were screened for salinity and drought. Sunflower, castor and vegetable crop species have been evaluated for tolerance to salinity and drought. Root elongation and increase in root number were indicators of salinity tolerance functioning as osmotic adjustment.

Modified Seed priming

A simple priming technique was developed for vegetable crop species which has resulted in 3-4 days early flowering. The time required for initiation of germination varies for each vegetable species. This time required was first noted before imposing the priming treatment. For example if a particular species took 30 hours to initiate germination, then one part of the seed were soaked for 15 hours and then dried at room temperature for 7 days. Another set of seeds is soaked in distilled water for suboptimum time for 24 hours and dried in room temperature. Both sets of seeds were then sown in the field and their field performance was evaluated to select the treatment that has given higher yield. It was observed that this modified priming technique enhanced flowering (3-4 days) and increased the productivity of few vegetable crops such as tomato, chilli, bottle gourd, water melon, bitter gourd and few cucurbits. This innovative technique can be used effectively to increase the productivity of few vegetable crops.

Propagation of native plants

Simulating natural condition

It was observed that seed dormancy can be broken down when the natural conditions are simulated. After seed dispersal of a species the seeds are exposed to natural conditions and start germinating with the advent of rains. This hypothesis was verified in the case of few species. In the case of wild *Phaseolus* and *Mezquites, Prosopis*, the seeds are dispersed in the hot summer and exposed to high temperature. It was observed that exposure of seeds of wild *Phaseolus* and *Prosopis* to a temperature of 80^{o}C and sulphuric acid treatment could break seed dormancy. In the case of wild chili, *chile piquin* and wild *Brassica*, the seeds are dispersed in winter and exposed to low temperature. Exposure of these seeds to cool low temperatures at 4^{o}C centigrade could break seed dormancy. This needs to be confirmed in other species. I confirmed this hypothesis in the case of wild chilli, Chili piquin and cactus.

Novel technique for inducing germination and propagation of wild chilli, "Chile Piquim"

Chile piquin, a wild chilli (*Capscicum annuum* aviculare) is of high demand and high commercial value in Mexico. It is harvested by the farmers from its wild habitat for difficulty in breaking seed dormancy it could not be utilized for immediate sowing. The seeds are dispersed in December and exposed to low temperature and start germinating with the advent of rain showers in next July. These seeds were mixed with extracts of cowdung and exposed to a low temperature of 4^{o}C for 7 days. This treatment immediately terminated the seed dormancy and seeds started germinating when sown in pots. Recently the Chile piquin seeds when treated with warm water at 80^{o}C and sulphuric acid at 50% for 15-20 minutes followed by washing in water to remove acid led to induction of seed germination in *Chile piquin*. Using these techniques it was possible to propagate and transplant the seedlings in the field for the first time without waiting for the onset of rains.

Conservation and Creation of a Germplasm Bank of Cactaceae at the Seedling Stage in a Green House Nursery

There is a great necessity to develop efficient techniques for the propagation and conservation of the endangered species as well as the formation of a germplasm bank, which could be available for the users, researchers and green house nurseries. For a long time, scientists have been trying to induce germination and propagation of Cactaceae, but have attained little success. Maiti et al. (2002) reported management and intensive production of species of Cactaceae in a green house nursery. Later, a more efficient and very simple technique was developed by sowing the seeds directly on nicely sieved sterilized river soil in plastic pots for inducing germination and seedling development of many species of Cactaceae. Using this simple technique, a large number of species of Cactaceae were successfully germinated and propagated in plastic pots and conserved in a green house nursery (Maiti et al., 2002). The technique is described in detail in the following.

Methodology. The technique for inducing germination and propagation of several species of Cactaceae as adopted by Maiti et al. (2002) consisted in sowing the seeds in replications in plastic pots with nicely sieved and sterilized river sands. Two to three holes were made at the bottom of the pots for supplying irrigation from below on a tray. Later, the pots were covered with polyethylene transparent film and then placed in a growth chamber at 28-30°C and under continuous light. The soil medium was kept under water-saturated condition until the seedlings were fully emerged. Afterwards daily irrigation was not required but occasional irrigation keeping the seedlings to a degree of water stress stimulated their growth. Following emergence, irrigation was withheld for one or two days before irrigating again. This process was repeated and after 15-20 days after emergence, the trays with the plastic pots containing the seedlings were taken out of the growth chamber and kept near the window for a slow acclimatization process. Now water was applied only once after 7-10 days depending on the species. This short term discontinuous irrigation and water stress were observed to accelerate seedling growth more than continuous irrigation. After about one month, the pots with seedlings were transferred to the green house. Water supply was given in the trays after 15-20 days, thereby exposing the developing cactus seedlings for periodic water stress, thereby accelerating the seedling develpment and development of spines and areoles varying among species. After full emergence, a thin layer of river sands should be added to give support to the growing seedlings. Continuous irrigation led to seedling rots owing to the xerophytic habit of cactus. Utilizing this technique, a large number of germplasm of Cactaceae could be propagated and conserved at the seedling stage. Germplasm bank of cactus species The procedure developed by Maiti et al.(2002j) was adopted to induce germination and propagation of a high number of cactus species, thereby maintaining and conserving a germless bank in the same plastic containers. Owing to the slow growth habit, the seedlings could grow in the same pot for more than a year and could be finally transplanted in their natural habitats only by breaking open the walls and transplanting the seedlings directly in holes made in the soil or distributed. Using this simple technique 62 species of Cactaceae were propagated with germination percentage of more than 90%.

Increasing crop productivity under sustainable agriculture

Increasing global warming associated with salinity and drought is affecting crop productivity under sustainable agriculture. This urges the necessity of multidisciplinary research team working together. I feel strongly that using simple low cost technology mentioned above the physiologist could screen in mass scale the hybrids and varieties of various crops with high yielding back grounds and select crop cultivars tolerant to salinity, drought and other abiotic stresses. It is expected that the crop cultivars tolerant to salinity and drought have high potential to increase crop productivity under sustainable agriculture prevailing in the farmers fields. Apart from this the soil scientists and agronomist could adopt their inputs to improve crop productivity under these stress prone areas.

FOREST SCIENCE

During 3 years stay as visiting research scientist in Forest Science Faculty, UANL, Dr. Maiti has made significant contribution in various areas. Among these may be mentioned 1) Identification of woody plants with open leaf canopy which are related to high photosynthetic capacity, high productivity and high wood density., 2) Selection of woody species with high carbon sequestration capacity which are recommended to plant in factory cites, road sides, citied with high carbon pollution in order to reduce carbon load from the atmosphere. 3) Identification of ecophysiologically efficient woody plants., 4) Classification of woody plants on the basis of branching pattern and branching density., 5) Prediction of timber quality and its utility on the basis of wood anatomical traits.

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