

Competitiveness and hardiness of weeds: a silver line for crop improvement

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India's biodiversity is well known as a vast treasure of plant genetic resources (PGR) occupying over 45,000 known species representing 11% of earth's flora. Thus we are in position to launch massive crop improvement programmes for future agriculture. With the advancement in the molecular and gene technology, and their easy access provide us liberty to transfer the desirable gene across the genera and species. Thus it expanded the horizon for exploration of genetic diversity towards crop improvement in shorter duration with high throughput; however, success is yet to be realized in true sense. Without undermining the other sources of genetic materials (viz., model species, wild species and micro-organisms), competitiveness of weeds and their better ability to survive under adverse conditions and more importantly their co-existence with crop plants make them a potential and alternate source for trait-based gene transfer into crop plants.

Key words: Competitiveness, Hardness, Stress, Tolerance, Weeds

The competitive ability of weeds can be adjudged by the ability of weeds to gain a larger portion of limiting resources than does the main crop. As weeds frequently challenge our control measures and continuing in doing so, the first target of researchers should be to identify the traits which make weeds strong competitor of crop plants. Once such traits can be identified, then next step would be to identify genes responsible for those traits and transfer them into crop plants. This will help in negating the strength of weeds. Although, this simple strategy can equals the crop plants as weeds on strength basis, yet efforts need to be made from every corner of the science for which an understanding of the traits (strengths) and their molecular basis seems to be prerequisite.

Tolerance to abiotic stresses

Abiotic stresses lead to disturbance in metabolic processes and internal homeostasis and damage to macromolecules which are otherwise

vital to the normal cellular functions and maintenance. Understanding of pathways induced in response to abiotic stresses, prompts scientists to raise transgenic plants with the insertion of desirable traits for abiotic tolerance. However, only a partial success was achieved, so far, which can be ascribed mainly to the abnormal phenotypes, loss of vigour or yield penalties along with the insufficient or slow protection against the stress factors.

Salinity: Weed species *Diplachne fusca* was reported to be extremely salt-tolerant as well as dehydration tolerant due to its tremendous potential of osmotic adjustment on account of high glycine-betaine accumulation, hence may be considered as a source for genetic material for the breeding of salt stress tolerant crop. *Echinochloa crus-galli*, a prominent weed of rice field, possessed very high degree of salt tolerance on account of high osmotic adjustment, less MDA content (a measure of lipid peroxidation and membrane damage) and lower

content of putrescine and spermidine in leaves in response and high antioxidant potential.

Drought: Drought is another important stress factor causing heavy loss to agricultural production globally and more so in India. *Oropetium thomacum* is abundant in the area around Kailana near Jodhpur, and sometimes it covers almost all the ground between some scattered vegetation. Physiological and molecular features during dehydration and rehydration, classify it as a resurrection plant. Metabolic adaptation of this species can be characterized as high content of sucrose, raffinose and stachyose and low content of monosaccharides in dehydrated leaf tissues alongwith the presence of two prominent water stress proteins namely the LEA dehydrin and aldose reductase. A comparison in induction pattern of these proteins in dehydration-sensitive maize and *O. thomacum* indicated that aldose reductase protein was only expressed in desiccation tolerant embryos in maize

but never in leaves, however, it was present in desiccated leave of

O. thomacum. These suggested that the presence of aldose reductase protein in the leaves can be considered as a marker for desiccation tolerance at least in monocotyledonous plants and

O. thomacum can be a suitable source for molecular manipulation of crop plants for drought tolerance.

Flooding: Flooding cause a vast damage to agricultural production globally. Submergence creates the anaerobic condition in which aerobic respiration cease and glycolysis dominate leading to the production of ethanol which above the threshold is toxic to most of the crop species. Tolerance to ethanol and the ability to metabolize key intermediary substrates under anaerobiosis were studied in . Results indicate that *Echinochloa crus-galli* *E. crus-galli* possesses an inherently high tolerance to ethanol and is able to metabolize ethanol (45-fold greater than endogenous levels) in the absence of oxygen. Beside ability of this weed to metabolize carbohydrate intermediates and to synthesize lipids indicated that mechanisms exist for providing the carbon intermediates for biosynthesis, particularly membrane synthesis for growth, even in the absence of O_2 . For submergence tolerance, crop plant can be engineered to enhance ethanol tolerance by incorporation a gene(s) like alcohol dehydrogenase and for this purpose, *E. crus-galli* emerges as a potential species for genetic material.

Ultraviolet-B radiation: Environmental concerns about ozone depletion arise from the fact that the ozone layer in Earth's atmosphere is an effective filter for the biologically harmful ultraviolet-B radiation present in sunlight. Research conducted over the past decade yielded a great deal of detailed information on biological responses to ultraviolet-B exposure. Amount and intensity of ultraviolet-B radiation which reach to the earth surface has increased considerably as a result of stratospheric ozone depletion. ultraviolet-B radiation is known to be detrimental to plants

and showed to cause inhibition of photosynthesis and growth for several species. Performance of four important weed species i.e. *Abutilon theophrasti*, *Amaranthus retroflexus*, *Digitaria sanguinalis* and *Chloris virgata* was evaluated under elevated ultraviolet-B radiation. After 2 weeks of radiation, growth and dry mass of shoots decreased with increasing ultraviolet-B radiation in all the weed species except for *D. sanguinalis*. Different components of antioxidant defence mechanism altered in species-specific manner. Based on the findings of the experiment, *D. sanguinalis* was the most tolerant and *A. retroflexus* the most sensitive to elevated ultraviolet-B radiation. Weed species like *Poa annua* and duckweed (*Spirodela punctata*) were found to be tolerant to ultraviolet-B, and it was concluded that phenol oxidizing peroxidases concurrently contribute to ultraviolet-B protection.

Ozone: There is nearly global consensus that O_3 adversely affects growth and development of most of the plant species. Literature available on the topic showed variations in response of plants species to O_3 . Exposure to elevated O_3 typically results in suppressed photosynthesis, accelerated senescence, decreased growth and lower yields. Studies have suggested that O_3 can influence not only growth of a particular crop plants but also may change the interaction with other species i.e. crop-weed interaction and efficacy of herbicides. In a comparative study, cotton (*Gossypium barbadense*) found to be more sensitive to O_3 than nutsedge.

Advances in biotechnological techniques for raising transgenic for desirable traits pave the way towards development of O_3 -resistant crop cultivars which can help in maintaining crop productivity under futuristic climate change scenarios in which tropospheric O_3 level is projected to be much higher than its current level. Comparative studies involving crop and associated weed species seem to be useful especially to find out the species which can be a potential donor of genes responsible for O_3 tolerance.

Temperature: Low and high temperature always associated with

oxidative stress which adversely affects the crop performance and yield. The effect of thermal stress on the antioxidant system was investigated in two invasive plants species, *Eupatorium adenophorum* and *E. odoratum* with the aim to explore the relationship between the response of antioxidant enzymes and temperature tolerance in the these invasive weeds. In *E. adenophorum*, the coordinated increase of the activities of antioxidant enzymes was effective in protecting the plant from the accumulation of reactive oxygen species at low temperature. However, no such protection was observed during the heat treatments as evident from the higher level of lipid peroxidation in *E. adenophorum* than under cold stress. In *E. odoratum*, reverse trend was observed in terms of membrane damage, as indicated by low monodehydroascorbate content, and the coordinated increase antioxidant enzymes was observed in heat-treated plants. But the antioxidant enzymes were unable to operate in cold stress. This indicated that *E. odoratum* plants have a higher capacity for scavenging oxygen radicals in heat stress than in cold stress. Differential responses of antioxidant enzymes may be one of the possible mechanisms of the differing temperature tolerance of the two weeds species and based on such capacity of these weeds species, genes can be transfer into crop plant.

Heavy metals: In general, accumulation of heavy metals depend upon the plant species and the metal concentration in the media. A study was conducted on the native flora growing on fly-ash affected areas near thermal power plant, Tanda, Uttar Pradesh, India for accumulation of toxic heavy metals. *Hydrilla verticillata* (an aquatic weed) was found to be the most efficient metal accumulator and it was further emphasized that of this weeds can be utilized for phyto-remediation of the water-bodies. studied the potential of grasses for the copper tolerance and found that elephant grass (*Pennisetum purpureum*) can be a good candidate for growth on Cu-contaminated soils. It was also observed that *Eichhornia crassipes*

accumulated high level of metals Fe, Mn and Cu while *Spirodela polyrhiza* accumulated Cd, Pb and Cr even when the metal concentrations were not high in the effluent. These two plants were found to be the best accumulators at different contaminated site. Beside other weeds species like *Typha angustata*, *T. latifolia* *Alternanathrea philoxeroides*, *Phragmites karka* and *Mollugo verticillata* also have potential of metal accumulation. The capability of these weeds to accumulate and tolerate heavy metals can be utilized for the transformation of the some crops with a partitioning into not edible parts enabling them to grow in heavy metal polluted areas.

Climate change: Studies showed that many weeds survive far better in the high-heat and high atmospheric carbon dioxide (CO₂) environment. Thus, as rise in CO₂ level is almost sure, many crops such as rice and corn face the dual problem of increased competition from weeds and reduced yield in a harsh environment due to global warming. Lessons can be learnt from the weed species which showed greater potential to cope up with the global warming effects and then either breed or genetically engineer the genes that make weeds a 'tough plant' into the food crops can be a good and desirable throughput. For example, rice does not produce seeds when temperature is high (above 35 °C) and on the same time and cannot compete with a closely related weedy rice in a high CO₂ environment. Inserting genes from weedy rice into common rice, scientists can create hybrid rice that can withstand the heat and out-compete the weeds, thus cope up with global warming. A study was conducted in 'Free Air CO₂ enrichment' (FACE) to see the effects of elevated CO₂ on physiological, biochemical and antioxidant defence system in greengram and associated weeds *Euphorbia geniculata* and *Commelina diffusa*. All together, results of this study suggested that elevated CO₂ affect the overall growth of plants and crop-weed interaction changed in favor of weeds on account of higher benefit to weed species in terms of

growth and development and photosynthesis. A unique finding of this study was adaptive potential of weed species '*Euphorbia geniculata*' to high atmospheric CO₂ which showed higher transpiration and stomatal conductance to cope up with high temperature associated with rising CO₂, however, such adaptation was never evident in greengram.

Tolerance to biotic stresses

Weeds can be potential tool for the development disease resistance in crop plants. A good number of genes were identified and already incorporated into modern wheat and other crops for rust and virus resistance through conventional breeding programmes. Below is the list (Table 1) of some important genes which are incorporated from weedy plants into wheat for disease resistance.

Incorporation of specific rust-resistance genes in wheat and their confirmation through biochemical and molecular markers was tested. Leaf rust-resistance lines were developed by incorporating *Lr9* gene from *Aegilops umbellulata* and *Lr19* and *Lr24* from *Agropyron elongatum* into the four rust-susceptible, Indian wheat cultivars LOK-1, HUW234, J28 and K68 through a backcross breeding program and presence of LR19 was confirmed in four lines. The leaf rust-resistant line with *Lr19* as crossed with the leaf rust-susceptible wheat cultivar 'Agra Local' and F₂ plants were tested and found to be resistant. Further, efforts are being made to confirm the presence of other leaf rust-resistance genes (*Lr9* and *Lr24*) with the help of RAPD/STS markers.

From the annual weed barnyard grass *E. crus-galli* two novel defensins proteins Ec-AMP-D1 and Ec-AMP-D2 that differ by a single amino acid substitution were isolated by a combination of different chromatographic procedures. Both defensins were active against several phytopathogenic fungi and the oomycete *Phytophthora infestans* at micromolar concentrations. The Ec-AMP-D1 showed higher activity against the oomycete than Ec-AMP-D2. Novelty of the antifungal *E. crus-galli*

Table 1. List of the disease resistance gene and their sources

Disease	Gene	Source
Leaf rust	<i>Lr9</i>	<i>Aegilops umbellulata</i>
	<i>Lr24</i>	<i>Agropyron elongatum</i>
	<i>Lr19</i>	<i>Agropyron elongatum</i>
Powdery mildew	<i>Pm12</i>	<i>Aegilops speltoides</i>
Wheat streak virus mosaic	<i>Wsm1</i>	<i>Agropyron elongatum</i>
Hessian fly	<i>H27</i>	<i>Aegilops ventricosa</i>

defensins protein was the presence of C-terminal region of the molecule as the main determinant of the anti-fungal activity. Bioassays for insect resistance showed that *SaPIN2a*-over-expressing transgenic tobacco plants were more resistant to *Helicoverpa armigera* and *Spodoptera litura* larvae, two devastating pests of crop plants.

SUMMARY

Weeds can provide an alternative potential source of important genes for generating abiotic and biotic stress tolerant transgenic crop plants as well as for other aspect of crop improvements. Utilization of weeds as a source of genetic material has certain advantages over the wild species, microorganism or model plant species. Co-existence of weeds and crop plant ensures better chance of success and provides better control over other co-regulated processes. Another benefit of weeds as a source of genetic material can be seen in terms of cost of fitness and yield penalty. As of now, except few successful examples, most of the transgenic hardly showed any success outside greenhouse in actual environment. Reason for such a failure can be ascribed to the dissimilarity of donor and receptor species and the difference in their natural habitats. Relatedness of the weeds and crop plants, and similarity in their habitat further ensures the better chance of survival.

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