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Induced Variations, Selections and Germplasm Conservation in Selected Tree Species for Afforestation Programs on Degraded Soil Sites

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Abstract: The study is a part of tree improvement program, carried out at Biomass Research Centre, Banthra of this institute, on two fast growing leguminous tree species (*Acacia nilotica* and *Prosopis juliflora*) suitable for wood fuel production on wastelands (pH 8.6 to 10.5). It included treatment of seeds with various doses of gamma rays (10 to 50 krad) followed by layout of field trials at population density of 10,000 plants ha^{-1}. Species performance evaluated after four years revealed differences in growth and productivity potential of plants particularly at 40 krad dose level as compared to untreated control plants. Striking variations were observed at individual tree level in treated plants for vigor and morphological traits particularly tree form (straight, bent or crooked), bole (single, forked and multiple boles), branching pattern (compact or spreading type), thorn trait (thorny, or thornless) and yield associated traits (trunk thickness and height). Selected desirable phenotypes (Candidate and Plus trees) were multiplied vegetatively through air layering, rooting of cuttings and macro-propagation technique and conserved in clonal gardens for production of quality germplasm for expanding agro-forestry plantations on stressed soils. The study revealed potential of mutation breeding in inducing greater variability without any adverse effects on plant growth of non timber species raised for short rotation in agro-forestry programs on stress soils.

Key words: Fuelwood species, sodic soil, gamma rays, variability, selection propagation, conservation

INTRODUCTION

In many developing countries of the world, like India, forests are over utilized for fuel, fodder and timber resulting in depletion of genetic resources, desertification and ecological imbalance. Short rotation fuelwood forestry programs on degraded lands has gained immense interest in order to meet the basic need of various forest products for rural communities and to rehabilitate the fertility status of these lands for sustainable development. However, in spite of intensive efforts and inputs, limited success has been achieved in most of these plantation programs as quality germplasm were used. Except for a few studies on selection and breeding of timber trees, no systematic efforts have been made in this direction in fuelwood trees raised for short durations. In conventional tree improvement programs, 20 to 25 years are needed to identify a genetically superior elite tree because of their perennial nature, long life cycle and complex breeding systems. Mutagens have been extensively used for induction of new variability in several crop plants, horticultural species including medicinal and other value added plants[1,2]. However, most of the fuelwood trees are lesser-known and neglected species. These are raised for short rotations on fragile and degraded soil sites.

Extensive studies have been carried out at Biomass Research Center of this institute to identify promising species for short rotation fuelwood forestry programs and to upgrade their productivity potential through silvicultural and tree breeding practices[3-8]. In the present study role of gamma rays in inducing changes in growth behavior and phenotypic character of treated plants of non timber fuel wood tree species such as *Prosopis juliflora* and *Acacia nilotica* has been investigated at maturity age. Earlier such studies are scanty except for some preliminary reports[9-11]. Both of these *Leguminous* species are well known for their wide range of adaptability, high regeneration potential and nitrogen fixing ability on waste lands[12]. The study would help in identification, propagation and conservation of desirable phenotypes in order to create a resource base of germplasm for rapidly expanding plantation programs.

MATERIALS AND METHODS

Site details: The soil of the experimental area was highly alkaline (pH 8.6 to 10.5) with carbonate and bicarbonate as the dominant anions. Kankar nodules ranging from 10-15 mm in size were common at 45-75 cm depth of the soil profile. The organic carbon content varied from

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0.03 to 0.06 %. The soil has high exchangeable Na+ content (5.67-12.28 meq 100 g^{-1}). In addition to this, these soils also exhibit structural problems such as crusting, hard setting and water logging associated with poor infiltration rate.

Seed treatment and trials: Seeds of *Prosopis juliflora* Swartz and *Acacia nilotica* Ex. Del. (Family Leguminosae, sub-family Mimosoideae) were collected from site adapted trees of five-year-old trial plantations on sodic lands. Dry seeds having 11.2 to 12.4% moisture content were irradiated with 10, 20, 30, 40 and 50 krad gamma rays in a gamma chamber 900 -a Co^{60} source at our institute. Nursery seedlings were raised in perforated polybags filled with a mixture of soil+ sand+ leaf mold in the ratio of 1:1:1 in along with untreated control seeds. Number of seeds per treatment and replication was 75. Field trials were laid in a subtropical semiarid environment at Biomass Research Center, Banthra, Lucknow (26° 45'N, 80°53'E) of this institute using 7-8-mo-old saplings. Transplanting of saplings was done in 50x50x 50 cm deep pits filled with amended soil (one bucket sand + farm yard manure in each pit). Plants were spaced at 1.0x1.0 m spacing corresponding to a density of 10,000 plants ha^{-1}.

Growth and biomass productivity of 4-yr-old plants were studied in control and treated population. Population diversity in control population and variations induced as result of mutagenic treatment were screened at maturity age, selected and multiplied vegetatively through stem cuttings, air layering and juvenile top cuttings as suggested by Goel and Behl[7]. The selected material was conserved in clonal gardens for future use as planting stocks.

RESULTS AND DISCUSSION

Field performance: Data recorded for 4-yr-old plantation revealed marked differences among two species as well as control and treated plants in respect to their plant height, diameter, basal area and productivity (Fig. 1). In general *P. juliflora* showed high plant establishment (100%) at all the doses except at 50 krad where it was 93%. In *A. nilotica* plant establishment was relatively low (53 to 68%) at different dose levels. Plants were taller in *P. juliflora* where as growth rate was slow in *A. nilotica.* Stem thickness, an important parameter related to productivity, showed a reverse trend. Average thickness of plants at 50 cm from ground level was greater in *A. nilotica* as compared to it in *P. juliflora*. Comparing growth potential of control and treated plants, an increase in respect to plant height, diameter and basal area of plants was recorded after treatment. However, no dose specific effect of gamma rays was observed in both the species. In *A. nilotica* significant growth stimulation was recorded at 40 krad dose level as compared to control plants ($p<0.05$). Goel[10,11] reported stimulatory effect of gamma rays on growth of the plants. Overall biomass yield was found to be enhanced in treated plants of both the species as compared to control plants except at 50 krad dose level where it was reduced. Higher productivity at certain dose level after treatment could be due to faster growth of the plants particularly in terms of height and diameter which determines the amount of harvestable wood[6], Stem wood shows maximum contribution irrespective of doses. In *P. juliflora* contribution of branch wood and leaf biomass was higher as compared to same in *A. nilotica.* In control plants average stem biomass was 2.49 kg $plant^{-1}$ in *P. juliflora* and 4.39 kg $plant^{-1}$ in *A. nilotica.* In treated population, a marked increase in biomass yield was recorded in *P. juliflora* (2.56 to 6.5 kg $plant^{-1}$) and *A. nilotica* (2.15 to 7.54 kg $plant^{-1}$). On area basis *P. juliflora* with 71.8 t ha^{-1} biomass showed superiority over *A. nilotica* (40.8 t ha^{-1}) irrespective of treatment. This was because of its higher plant establishment (9896 plants ha^{-1}) in *P. juliflora* as compared to *A. nilotica.* Plant growth and biomass yield showed retardation after 40 krad dose level in both the species.

Phenotypic variations and selection: A large population in *P. juliflora* (1695) and *A. nilotica* (1190) was screened for occurrence of morphological variations. In control population such variations were 3.04% in P. *juliflora* and 2.68% in *A. nilotica* whereas, after treated frequency of such variations increased markedly (5 to 12%). In both the species, selection intensity was kept very high for plus tree selection. Most of the variation observed included dominant or suppressed trees, bent or crooked forms, forked or multiple stems and short or long clear bole. However, in treated population tremendous diversity was observed in various morphological characters in spite of even aged plants, similar site and cultural conditions. It included vigorous trees with single straight bole, long or short clear bole, thick or narrow trunk, permanent or caduceus thorns, thorny or thornless forms and compact or spreading branches (Fig. 2-10). Selections were made from gamma rays treated population for "Candidate" and "Plus" trees on the basis of superiority in yield associated characters and morphological traits. Variations in respect to morphological traits were higher in *P. juliflora* as compared to *A. nilotica.* Occurrence of thornless plants has been reported in exotic germplasm of *Prosopis* species[12,13]. However, it was rare trait in indigenous germplasm of *P. juliflora* except for presence of natural hybrids with out thorns or caduceus thorns.

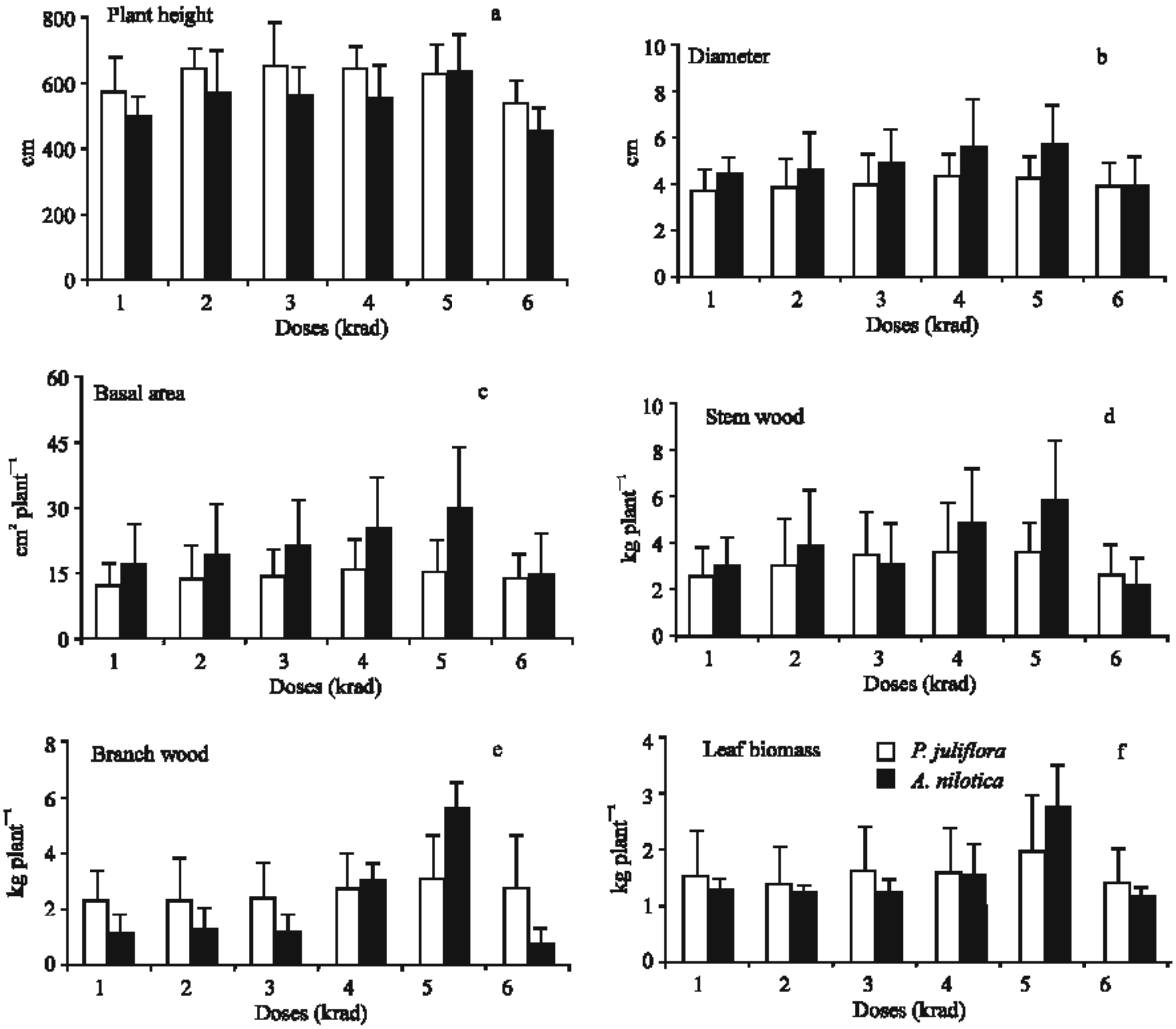

Fig. 1a-f: Performance of control (#1) and gamma rays treated plants (# 2 to 6 :5, 7.5, 30, 40 and 50 krad) of *A. nilotica* and *P. juliflora* at the age of five years

Fig. 2: A control plant of *P. juliflora*

Selected variants have direct or indirect use in various plantation programs depending on the objective. For example variants with straight large clear bole or compact branching are useful for agro-forestry programs to enhance soil fertility with out any adverse shading effect on under ground crop growth. Similarly presence of thorns restricts social acceptance of these species for use as fuel wood. Therefore plants having small and caduceus thorns are eco-friendly and would help in easy handling of wood for fuel and fodder purpose. Plus trees having thick bole were screened for industrial energy purpose while phenotypes with multiple branches were selected for use as raw material for power generation in gasifier systems. Seeds of individual selected plants were collected for raising individual tree progenies for further selection, multiplication and confirmation.

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 3-8: Morphological variations in *P. juliflora*

Fig. 3-5: Variants showing single, bifurcated and multiple boles

Fig. 6: A variant showing absence of thorn

Fig. 7-8: A twig of thornless and thorny plant of *P. juliflora*

Fig. 9

Fig. 10

Fig. 9-10: Variation in growth and branching pattern in *A. nilotica*
Fig. 9: A variant showing crooked and bent stem
Fig. 10: A variant showing large and clear trunk

Fig. 11

Fig. 12

Fig. 13

Fig. 11-13: Clonal propagation of selected variants
Fig. 11: Rooting induction in young branches through air layering
Fig. 12: A rooted branch cutting of *P. juliflora*
Fig. 13: Macro-propagation under protected environment nursery

Clonal propagation and germplasm conservation: Desirable variants (phenotypes), having characteristics of major importance as thornless, vigorous, straight bole and compact branching, were selected, multiplied vegetatively and conserved in clonal gardens. This technique included propagation of selected variants through stem cuttings and air layering (Fig. 11 and 12). Success was poor in *A. nilotica* as compared to *P. juliflora* irrespective of technique adopted. Induction of rooting in stem cutting was limited (6 to 23.8%) as compared to success achieved in air layering of branches (25 to 70%). However, it is a time consuming task. Recently High-Tech-Low cost Protected Environment macro-propagation technique has been developed at Biomass Research Center, Banthra of this institute (Fig. 13). The technique offers possibility for large scale multiplication of selected phenotypes in specially designed poly-houses having UV proof polyfilm cover and controlled environment (humidity 80% and temperature 30°C). It included rooting of small juvenile top cuttings (10 to 15 cm long) in a sterile potting media "Vermiculite". This technique was more successful in *P. juliflora (*40 to 80%) as compared to *A. nilotica* (10 to 25%). Earlier Goel and Behl[14,15] reported that both these species are difficult to root species and differences in rooting potential of various species may be because of differences in their genetic nature. Several cultural and management practices particularly nature of propagating material, control of temperature and humidity inside the poly-house are crucial factors to optimize the success rate[15,16]. Conservation of genetic diversity in *usar* site adapted tree species was carried out by Dogra and Behl[17]. Ten clones of *Prosopis* have been conserved in vegetative clonal gardens for early production of quality planting materials for breeding purpose and future afforestation programs.

Thus study revealed that physical mutagens like gamma rays have potential to induce considerable diversity in morphological traits of leguminous tree species like *P. juliflora* without any adverse effect on growth parameters. Stimulation in growth and productivity of plants at certain dose level suggested need for further detailed studies. Species like *P. juliflora* showed greater effectiveness of gamma rays as compared to *A. nilotica.* Selection, propagation and conservation of germplasm helped in resource establishment for future use in commercial plantations.

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