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Allelopathic Potential of Some Prunus Species And Identification of Allelochemicals

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ABSTRACT

Allelopathy refers to biochemical interactions between all types of plant. This interaction either inhibitory or stimulatory effects of higher plants of one species (the donor) the germination and development of another (receptor) species. A field survey in Prunus cornuta, P. jacquemontii, P. armeniaca and P. amygdalus growing areas of Chamoli District were conducted with reference to the germination and growth of some companion crops at various sites of different soil fertility. Retardation in germination, growth and yield were noted in nearby Triticum aestivum (wheat) and Raphanus sativus (radish) plants particularly on those sites where the percentage of soil organic matter was low. It was also observed that the magnitude of interference gradually decreased as the distance from the tree increase. Aqueous and organic solvent extract of the aerial part of Prunus species were made and their residue were tested, after proper dilution, for their phytotoxic effect in germination and growth of the test crop. Residues of different extract showed inhibition in growth and germination of test species.

Keywords: allelopathy, bioassay, allelochemicals, Prunus species.

INTRODUCTION

Allelopathy-physiological and biochemical interrelation between individuals, which directly contact in space (allelopathic interaction) or in time (allelopathic post action), is the most important factor of growth, development and renewal of higher plants in their communities. The metabolites of plants, which are responsible to impose a kind of environmental stress on other plants growing in the vicinity of former, are known as allelochemicals. Their sources are plants excretion in broad sense viz. plant residues, root exudates, leaf leachates etc.

Farmers have observed problems related to allelopathy since the beginning of agriculture. For example, gardeners long ago observed that tomatoes grow poorly under walnut tree. Sorghum plant residues inhibit the growth of many weeds. Pyrethrum and Neem plant have definite insecticide properties. Studies so far have shown that allelopathy could be utilized to increase production of food grains, vegetables, fruits and forest tree, to decrease harmful effect of modern agricultural practices on soil health and productivity and to maintain the pollution free environment for our future generation. Increasing pressure on the agricultural land and forest can be solved by the concept of multiuse of land with multipurpose trees. Social and agro

forestry concept generated with the aim of maximum utilization of land for varies purposes. In hills social and agro forestry can be integrated with agriculture or the crop field can be protected by planting suitable peripheral trees but before plantation of the trees with agricultural land, their suitability and ecological impact on the surrounding should be identifies besides their economic and biomass productive factors.
Although it is not easy to demonstrate chemical effects of this kind in nature, there is unquestionable evidence that they do take place. For instance, it is well known that the compound juglone can prevent germination in many plant species. The leaves and the root exudates of *Juglane regia* contain a naphthalene glycoside that itself is not allelopathic. Only after its hydrolysis and oxidation by soil microorganism to hydrojuglone, the active inhibitor was finally formed [1,2]. Allelochemicals exert effects on division, elongation and ultra structure of the cell, membrane permeability, mineral uptake, availability of phosphorous and potassium in soil, stomatal opening, photosynthesis and respiration. These chemicals also interfere in the protein synthesis, in lipid and organic acid metabolism and porphyrin synthesis [3]. They also affect inhibition or stimulation of special enzymes, corking and clogging of xylum elements, stem conductance of water and internal water relation.

It is noteworthy that many species of plants, which have been widely used in medicine and are known to have powerful medicinal effect, have pronounced allelopathic effect also. *Prunus cornuta*, is a moderate or large tree up to 18m in length and distributed in the temperate Himalayas at the altitude of 1200-3600m. This is a multipurpose species used for cattle feed. This species is biomass productive, its timber is used as fuel and fruits are used for brewing liquors. *P. armeniaca*, is a moderate sized tree about 10m tall and found at an altitude of about 300m. Local inhabitants with nearby crop fields and in the garden often grow it. *P. jacquemontii* is wild shrub usually grown in high altitude region (3,000-3,500m) of Garhwal Himalayas. It is good fodder for sheep and goat and cultivated for peripheral plantation to protect their fields from erosion and feeding purposes for livestock. *P. amygdalus* is a tree upto 8m high, suitably cultivated in India at elevation of 760-2400m. Some *Prunus* species have already been implicated in allelopathy [4-8].

MATERIALS AND METHODS

Field studies were conducted near Chopta (Chamoli) for *P. cornuta* and *P. jacquemontii* and in Kulsari (Chamoli) for *P. armeniaca* and *P. amygdalus* where these trees were found growing in the vicinity of the crops, namely wheat, radish, barley, lentil and finger millet. The fertility ingredients of the soil of different sites, namely percentage of organic matter, available phosphorus and potassium were determined by the rapid Purdue test [6]. The *Triticum aestivum* (wheat) crop found to be more affected by *P. armeniaca* and *P. amygdalus* whereas *Raphanus sativus* (radish) crop found to be more affected by *P. cornuta* and *P. jacquemontii*. Therefore, further observations regarding growth and development of *Triticum aestivum* and *Raphanus sativus* were made at a distance of 3m from the trees to eliminate a direct shading effect. The observations of plant germination, height and yield were recorded by making four quadrate of $1m^2$ each, i.e. 3-4, 4-5, 5-6 and 6-7m from tested *Prunus* species. The fifth quadrate 7m from the tree was considered as normal, where the interference was considered zero [9]. Four different fields of almost the same height and fertility ingredients in each tested *Prunus* species were taken for the observational studies. The percentage reduction in germination was calculated by counting the seedlings in each quadrate after 5 and 2 weeks of sowing of *Trticum aestivum* and *Raphanus sativus* respectively and comparing them with the population of a normal quadrate where germination was considered as 100%. Data regarding height and yield were recorded after maturity of the crops, from the average of 20 healthy plants in each quadrate and compared with the average of the same number of healthy plants from the normal quadrate where the height and yield were considered as 100%. Finally the average of germination, height and yield of four different fields were calculated (Fig. 1).

The plant materials (aerial parts) were collected from mature fruiting trees and were shade dried and ground. Aqueous extracts were prepared from 40g material suspended in 1000ml double distilled water for

48h at temperature [10,11]. The extracts were vacuum filtered through Whatman filter paper No. 1 and dried in vacuum under reduced pressure.

For the bioassay of solvent extracts and characterization of allelochemicals, 1kg of dried and powdered material in each *Prunus* species was extracted with ethanol. After evaporation under reduced pressure, the residue was successively extracted in a Soxhelt apparatus with light petroleum (60-80^{o}), ethyl acetate and methanol. All extracts were dried in vacuum under reduced pressure.

The bioassay of different organic solvent extracts and the aqueous extract (400ppm concentration) was carried out using *Tritcum aestivum* in case of *P. armeniaca* and *P. amygdalus* and *Raphanus sativus* in case of *P. cornuta* and *P. jacquemontii* as the test crop. 50 mLof water and each organic solvent residue were dissolved separately in 50 ml of the solvent in which they were extracted and 2 mL of this solution was poured on to Whatman filter paper No. 1 in Petri-dishes (9cm diameter). In controls only 2 mL of the respective solvents were used. After evaporation of the solvent, 5 mL double distilled water was added and 10 seeds of the test crop were set in each Petri-dish and covered with another filter paper. Each extract and control treatments were replicated four times. All the Petri-dishes were kept in an incubator at 25±1^{o}C for approximately 72h. the percentage inhibition in terms of roots, shoot length and germination was calculated by considering and control as zero.

For characterization of allelochemicals the residues of the light petroleum extract and ethyl acetate extract of each tested *Prunus* species were subjected to column chromatography over silica gel (Merck) with gradient elution method. The light petroleum extract of *P. armeniaca* afforded β-sitosterol and kaempferol while ethyl acetate extract afforded aromadendrin, quercetin, β-sitosterol-β-D-glucoside, pleoside (domesticoside; 2-o-glucosyl-6-hydroxy-4-methoxy acetophenone) [12,13,14,15]. The light petroleum extract of *P. amygdalus* afforded β-sitosterol and naringenin while ethyl acetate extract gave aromadendrin, β-sitosterol-β-D-glucoside and persicogenein-3'-glucoside [16,17]. The light petroleum extract of *P.cornuta* afforded β-sitoserol and naringenin while ethyl acetate extract gave β-sitosterol-β-D-glucoside, prunasin and methyl-o-coumarate-β-D-glucoside [18,19]. The light petroleum extract of *P. jacquemontii* afforded β-sitosterol while the ethyl acetate extract gave β-sitosterol-β-D-glucoside, 13'-hydroxy mahuannin-A and pavetannin [20,21].

The bioassay of isolated compounds was carried out with 40ppm concentration of their respective solution. A similar procedure to that described previously was used.

RESULTS AND DISCUSSION

Field observations (Fig. 1), bioassays with extract (Fig. 2) and bioassays with isolated compounds (Fig. 3) led to the conclusion that inhibition in germination and growth and reduction in yield might be due to an allelopathic effect. In field studies, the percentage reduction in germination, growth and yield decreased as the distance from the tree increased, while suggest that the allelochemicals released from the tree inhibit germination as well as growth and yield of the test crop, and in turn affect the yield of the crop.

In all the cases the light petroleum and ethyl acetate extracts showed more inhibition than other extracts, with respect to parameters observed in the bioassays (Fig. 2), namely inhibition in germination, root length and shoot length indicated the presence of active/toxic compounds in higher concentrations.

The bioassay of isolated compounds of *P. armeniaca* revealed that kaempferol showed maximum inhibition to germination and growth of *Triticum aestivum* seedlings, whereas In case of *P. amygdalus* the significant inhibition was noticed when bioassay with isolated compounds with *Triticum aestivum* as test crop. The order of inhibition of the compounds was found as persicogenin-3'-glucoside> naringenin>aromadendrin. The isolated compounds of *P. cornuta* bioassay with *Raphanus sativus* as test

crop, significant effect was observed. The prunasin is more inhibitory effect on germination, root length and shoot length followed by methyl ester of melilotoside and naringenin. While in the case of *P. jacquemontii* the isolated compounds i.e. 13'-hydroxy mahuannin-A and pavetannin showed the inhibitory effect with *Raphanus sativus*.

The tannins passively interfere with the growth of nitrifying bacteria [23] and inactivate plant β-glucosidase [24,25], which may cause inhibition in the growth and germination of the test crop. These results substantiate that proanthocyanidins A-type are inhibitory when compared to other compounds at a concentration of 40ppm. Prunasin a cynogenesis of prunasin into benzaldehyde and HCN. Both HCN and benzaldehyde are potent allelochemicals [26]. Some of these isolated compounds are reported to affect various processes of plants. For example, kaempferol in inhibitory to the synthesis of ATP and acts as an energy transfer inhibitor and also inhibit the phosphorylation mechanism [27,28]. Numerous flavonoids and their glycosides produced are inhibitory to nitrifying bacteria and seed germination. Some flavonoids are reported to inhibit CO_2-dependent O_2 evolution and photophosphorylation of isolated chloroplast [29].

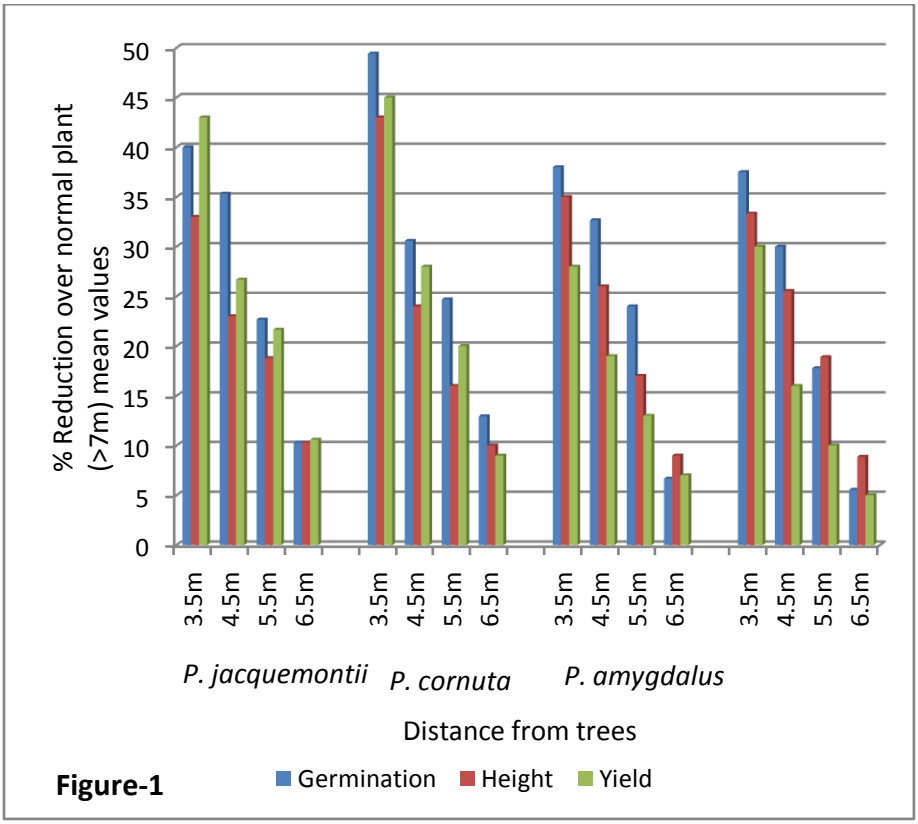

Figure-1

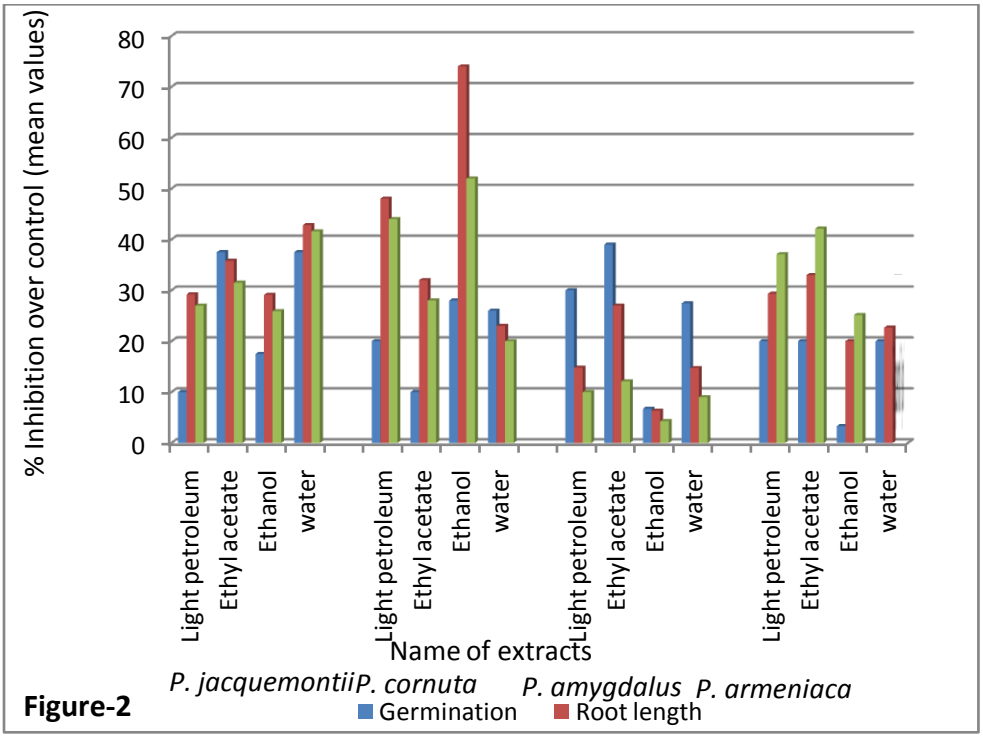

Figure-2

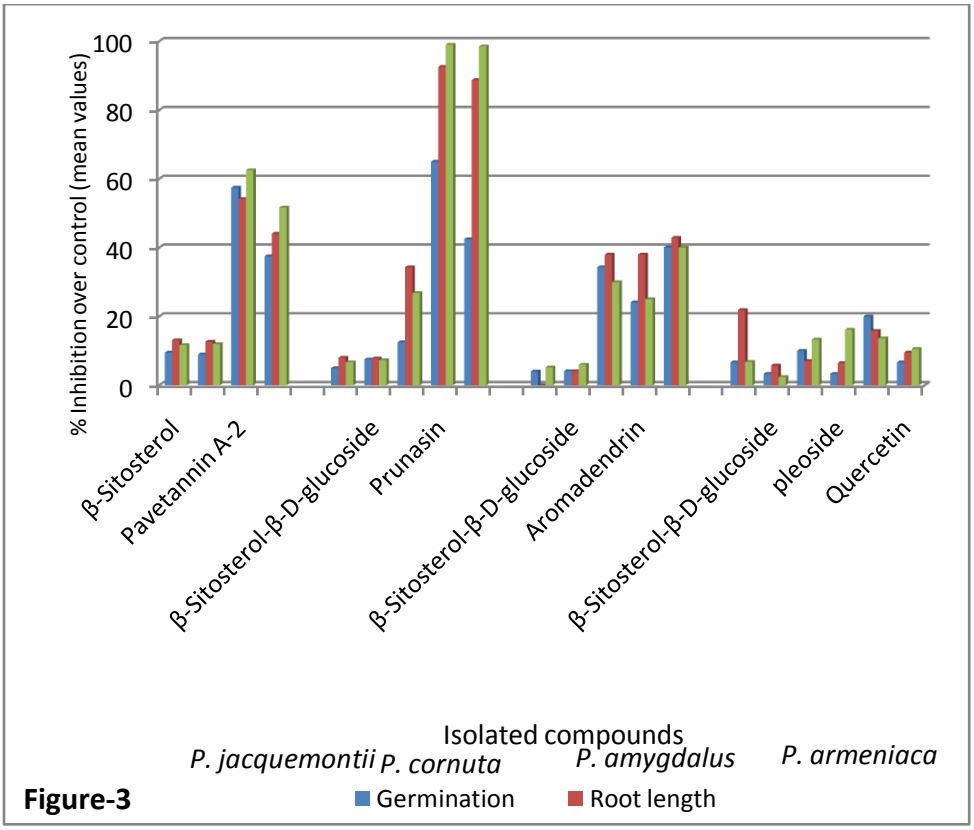

Figure-3

APPLICATIONS

In the nutshell, the outcome of this work is helpful in generating/strengthening the concept of social and agro-forestry with the aim of maximum utilization of agricultural land for various purposes. The observations and the results of the present study i.e. interaction behavior of tree on crop, can suggest the plantation of suitable combination of trees with the agricultural crop which would minimize the ecological misbalance and increase agricultural output. Suitable selected combinations of trees with crop will protect the soil erosion besides fulfilling the demand of local inhabitants for fuel, fodder and timber and thus may helpful in reducing the pressure on the surrounding forest.

CONCLUSIONS

The observation and the results of present study can suggest the plantation of suitable combination of trees with the agricultural crops which would minimize the ecological misbalance, increase agricultural output. It also protects the soil erosion besides fulfilling the demands of local inhabitants and thus may be helpful in reducing the pressure on the surrounding forest.

REFERENCES

[1] J. Friedman, Methodology in Allelopathic studies, Standard Bioassay, In First World Congress on Allelopathy, A science for the future, Cadiz, **1996**, 116.
[2] R.H. Whittaker, In Chemical Ecology, (eds., Sondheimer, E and Simeone, JB), Academic Press, New York, **1970**, 43-70.
[3] W. Larcher, In Physiological Plant Ecology, 3rd edition, Springer-Verlag, New York, **1995**, 26, 278 and 290.
[4] C.A. Jensen, Some mutual effects of tree roots and grasses on soil, *Science Series-2*, **1907**, 25, 871-874.
[5] O. Schreiner and H.S. Reed, Some factors influencing soil fertility, *USDA Bureau of soils*, **1907**, 40, 1-40.
[6] A. Manareshi, Soil sickness in tree nurseries, *Italian Agriculture*, **1953**, 90, 477-492.
[7] F. Vogel and E. Weber, Soil sickness in the fruit tree nursery, *Gartenbaiswiss*, **1931**, 5, 508-524.
[8] S.B. Horsely, Decomposition of the cyanogenic glucoside of *Prunus serotina*, a possible allelopathic mechanism, Bot. Soc. Am. Misc. Ser., **1979**, 157, 41.
[9] S.S. Narwal and M.K. Sarmah, Suppression effect of *Eucalyptus tereticornis* on the field crop, In Proceeding of the First National Symposium on allelopathy in agroecosystem, eds. P. Tauro and S.S. Narwal, Indian Society of Allelopathy, Haryana Agriculture University, **1995**, 11.
[10] A.C. Anaya, L. Ramos, J.G. Hernandez and R. Cruz, Allelopathy in Mixico, In Allelochemicals: Role in Agriculture and Forestry, ed. GR Waller, ACS Symposium series, American Chemical Society, Washigton DC, **1987**, 330, 89.
[11] J.J. Jimenez-Osornio, and S.R. Gliessman, Allelopathic interference in a wild mustard (*Brassica capestris*) and broccoli (*Brassica oleracea*) intercrop agrosystems. In Allelochemicals: Role in Agriculture and Forestry, ed. GR Waller, ACS Symposium series, American Chemical Society, Washigton DC, **1987**, 330, 89.
[12] M.S.M. Rawat, G. Pant, D. Prasad, R.K. Joshi and C.B. Pande, Plant growth inhibitors (proanthocyanidins) from *Prunus armeniaca*, *Biochemical Systematics and ecology*, **1998**, 26, 13-23.
[13] M.S.M. Rawat, D. Prasad, R.K. Joshi, and G. Pant, Proanthocyanidins from *Prunus armeniaca* roots, *Phytochemistry*, **1999**, 50, 321-324.
[14] D. Prasad, R.K. Joshi, G. Pant, M.S.M. Rawat, K. Inoue, T. Shingu and Z.D. He, An A-type proanthocyanidin from *Prunus armeniaca*, *Journal of Natural Products*, **1998**, 61 (9), 1123-1125.

[15] D. Prasad, R.K. Joshi, G. Pant and M.S.M. Rawat, Ephedrannin A from *Prunus armeniaca* root, *Fitoterapia*, **1997**, XVIII (3), 275-276.
[16] C.B. Pande, D. Prasad, R.K. Joshi, M.S.M. Rawat and G. Pant, Allelopathic potential of *Prunus amygdalus* and identification of allelochemicals, *Allelopathy Journal*, **1998**, 5(1), 83-88.
[17] M.S.M. Rawat, G. Pant and R. Kukreti, A novel persicogenin-3'-glucoside from the bark of *Prunus amygdalus*, *Phytochemistry*, **1995**, 38, 1519-1520.
[18] C.B. Pande, M.C. Purohit, M.S.M. Rawat, and G. Pant, Bioassay studies with allelochemicals from the bark of *Prunus cornuta*, Allelopathy: Field observations and methodology, eds., SS Narwal and P Tauro, **1996**.
[19] M.C. Purohit, M.S.M. Rawat, G. Pant, A.K. Nautiyal, J. Sakakibara and T. Kaiya, A methyl ester of melilotoside from the sapwood of *Prunus cornuta*, *Phytochemistry*, **1993**, 32, 431-432.
[20] R.K. Joshi, D. Prasad, C.B. Pande, M.S.M. Rawat and G. Pant, Allelopathic effect of root and bark extracts of Prunus jacquemontii on Raphanus sativus, *Allelopathy Journal*, **1997**, 4 (2), 329-334.
[21] G. Pant, A.K. Nautiyal, M.S.M. Rawat, J.K. Sutherland and G.A. Morris, Identification and Ab Initio Carbon-13 NMR assignement of a proanthocyanidin from *Prunus jacquemontii*, *Magnetic Resonance in chemistry*, **1992**, 30, 142-147.
[22] S.A. Brown, Lignin and tannin biosynthesis. In biochemistry of phenolic compounds (ed. JB Harborne), Academic Press, New York, **1964**, 361-398.
[23] E.L. Rice and S.K. Pancholy,) Inhibition of nitrification by climax ecosystems, additional evidence and possible role of tannins, *Am. J. Bot.*, **1973**, 61, 1095-1103.
[24] K.C. Spencer, Specificity of action of allelochemicals; diversification of glycoside. In Allelochemicals: Role in Agriculture and Forestry, ed. GR Waller, ACS Symposium series, American Chemical Society, Washigton DC, **1987**, 330, 275.
[25] R.K. Joshi, D. Prasad, M.S.M. Rawat and G. Pant, Allelopathic effect of aqueous extracts of leaves of *Fraxinus micrantha* on crops, *Allelopathy Journal*, **1996**, 3(2), 255-259.
[26] E.L. Rice, Allelopathy an overview, In Allelochemicals: Role in Agriculture and Forestry, ed. GR Waller, ACS Symposium series, American Chemical Society, Washigton DC, **1987**, 330, 8-22.
[27] C.J. Arntzen, S.V. Falkenthal and S. Bobie, Inhibition of photophosphorylation by kaempferol, *Plant Physiol.*, **1974**, 53, 304-306.
[28] D.E. Koeppe, R.J. Miller, Kaempferol inhibitors of cron mitochondrial phosphorylation, *Plant Physiol.*, **1974**, 54, 374-378.
[29] R.K. Joshi, D. Prasad, R. Nautiyal, C.B. Pande, G. Pant and M.S.M. Rawat, Phytotoxicity of Cassia fistula on *Triticum aestivum* seedlings, *Hill research*, **1998**, 11, 43.