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A review on herbicide 2, 4-D damage reports in wheat (*Triticum aestivum* L.)

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ABSTRACT
The studies of interaction among herbicides and crop plants have been done for many years. The herbicides have been used in the crop field to increase the crop productivity and grain yield. Many herbicides have been used in crop field for the purpose. The herbicide 2, 4-Dichlorophenoxy acetic acid (2, 4-D) has been used in crop field quite for a long time. Discovery of the weed killing properties of 2, 4-D has proved to be one of the most important developments in the agriculture. But unfortunately since long back all research papers, reviews and articles showed the effect of this herbicide on the non-target organisms. Here, this is an attempt to review the harmful effects of 2, 4-D on wheat plant especially as wheat is an important and major staple food of the world. The situation of environmental changes mainly originate from anthropogenic activities are being responsible for affecting plant growth condition. Since plants are sessile organisms and have limited mechanisms for herbicide application avoidance they need flexible means for acclimatization to changing environmental conditions. Hence in order to improve a plant protection, this kind of researches may be fruitful in understanding of mechanisms contributing to effect of herbicides on plant system.

Keywords: Wheat, 2, 4- Dichlorophenoxy acetic acid (2,4-D), Plant Protection.

INTRODUCTION

Wheat (Triticum aestivum L.) is one of the most important food crops of the world and a member of the family Poaceae that includes major cereal crops of the world such as maize, wheat and rice. Among the food crops, wheat is one of the most abundant sources of energy and proteins for the world population and its increased production is essential for food security [1]. Also, the largest crop area is devoted to wheat and the quantity produced is more than that of any other crop. This occupies about 17% of the world's cropped land and contributes 35% of the staple food [2]. Wheat is characterized by large genome size (approximately 17000 Mb) and 95% of wheat grown today is of hexaploid type, used for the preparation of bread and other baked products.

The studies of interaction among herbicides and crop plants had done been for many years. The herbicides had been used in the crop fields to increase the crop productivity and grain yield. The increase in the grain yield of crops is the necessity of today's world of exploded population. Many herbicides were used in crop fields for the same purpose. The herbicide 2, 4-D had been used in crop fields quite for a long time. Depending on the type of cereal crop, the weed spectrum, cultural practices and climatic factors, 2,4-D might be applied as salts, esters, amines or free acid formulations at rates ranging from 250 g to 2 kg/ha (rarely up to 4 kg/ha). The herbicide application is usually made when weeds and cereal crop plants are small.

Under the changing of socio-economic conditions, availability of the agricultural laborers is reducing day by day that hampered agricultural operations seriously. Therefore, herbicidal weed control is well established in many wheat growing countries including India. The extensive use of the herbicides depends on that it does not affect the grass plants.

The undesirable plants compete with crop mainly for space, solar radiation, nutrients, water and carbon dioxide. Through competition they damage the crop and cause reduction in yield of crop. Herbicides are compounds designed to control the development of undesirable plants that may interfere with the growing of commercial crops [3]. The discovery of the weed killing properties of 2, 4-D has proved to be one of the most important developments in the agriculture. But unfortunately since long back all research papers, reviews and articles showed the effect of this herbicide on the non-target organisms also.

Reports on use of 2, 4-D

Recently, 2, 4-D had been used by the author to study the reproductive biology of the plants. But as expected the results showed the effect of 2, 4-D on seedling growth, morphological parameters, biochemical parameters and cytological parameters of wheat plant which were supported by the published research articles. Here, this is an attempt to review the harmful effects of 2, 4-D on wheat plant especially as it is an important and major staple food of the world. 2, 4-D had been used during last more than 6 decades for the control of broadleaved weeds in wheat crop. It was first introduced in 1946 in the agricultural farms of Aguadilla, Puerto Rico. After that the herbicide was in widespread use in agriculture by the middle of the 1950s. But its misapplication produced the adverse effect on the crop plant and an extensive literature had been published in the past on the agronomic, physiological and biochemical effects of 2, 4-D on plant processes [4-14]. There were illustrations of some earlier work which showed the effects of 2, 4-D on different parts and processes of wheat plant.

2, 4-D applied at lower concentration (5 ppm) affected the growth of wheat at earlier stages (4-5 days of growth) and caused lower yield at maturity [15]. Hamner et al. [16] reported that the range of 2, 4-D application (1-1000 ppm) caused many deformities and toxic effects on the wheat germination. Klingman [4] found much sterility and considerable morphological abnormalities in wheat spikelets treated at or before the jointing stage resulted in greater reduction in yield. It was reported that 2, 4- D had much variations in response and quite noticeable among the cereal crops [17-18]. Wheat is susceptible to 2, 4-D injury from emergence to the four leaf stage and from jointing to the soft dough stage of growth [19-20]. Asana et al. [21] cultured two varieties of wheat containing 2, 4-D and found less tillers, unfolded leaves, spikelets and shorter stems lead to grain yield reduction. Olson et al. [22] suggested two critical stages in wheat development that reduced the yield i.e. early seedling period (1-5 inches tall) and boot stage (a few days before heading). Allen [23] concluded that seedling and flower stages appeared to be the most sensitive to 2, 4-D in cereal crops. Wort [24] suggested the influence of 2, 4-D on enzymes of (cucumber) plant system. The overdose spraying of 2, 4-D could reduce the yield by 8-20% in winter wheat varieties [25]. Klingman [26] suggested that the periods of greatest susceptibility are those of rapid growth, when there is a high rate of meristematic activity. Johanson and Muzik [27] suggested that 2, 4-D application at various stages of affected the overall growth of wheat. Meadly [28] reported the scattering of heads in wheat treated with 2, 4-D at early tillering stage. The effect of 2, 4-D on wheat is known to depend on the growth stage at which it is applied [29]. Wheat yields were reduced after 2, 4-D application at 3-5 leaf stage of the crop [30]. Root tip system of various plants (including cereal crops) had been widely used for determining the harmful effects of herbicides on DNA [31]. 2, 4-D application at four leaf stage and jointing stage could reduce plant height, delay maturity and reduce grains yield due to inhabitance of cell division and growth in the meistematic regions [14]. Chromosomal aberrations might be accepted as indicators of genetic damage induced by herbicides [32]. Often cells in the phloem of treated plants were crushed or plugged, interfering with normal food transport which could leave parts of the plant malnourished or possibly lead to death [33]. Many short-term studies were based on in vitro and in vivo, which could be used for the detection and monitoring of a wide variety of environmental chemicals with mutagenic and carcinogenic potentials [34]. Plants treated with 2, 4-D often exhibits malformed leaves, stems and roots because it affects plant metabolism by stimulating nucleic acid and protein synthesis which affects the activity of enzymes, respiration and cell division in crop plants [35]. Mamun and Salim [36] reported the predominance of broadleaf weeds (without herbicide application) in wheat field which reduces the grain yield of the crop. Wheat is susceptible to 2, 4-D and injured the crop at seedling and jointing stage of the crop which reduced the grain yield [37-38]. Mid boot stage treatment (stage 43) caused more visible injury than early stage (stage 22-28) treatment [38]. Dial [39] evaluated the tolerance of 2, 4-D in wheat plants. 2, 4-D induced sister chromatid exchanges in cultured immature embryos of wheat species which affects the crop yield [40]. The uncontrolled weed growth (without herbicide application) in wheat crop field reduces crop grain yield up to 57% [41]. The application of 2, 4-D at later stages of wheat growth reduced the wheat yield [42]. The systemic and selective herbicide 2,4-D is applied mainly to eliminate broad leaf species, where it initiates the action of natural plant hormone indole acetic acid when used in small amounts, in high concentrations it induces chromosome abnormalities [43]. The root stimulation and shoot retardation at juvenile stage or seedlings of wheat could be affected by 2, 4-D treatment [44]. Petroczi et al. [44] suggested the application of hormone like herbicide 2, 4-D on weeds had depressive side-effects depending on the wheat genotypes under field conditions. Turk et al. [45] suggested that stage 22-28 (2-8 tiller detectable) and stage 43 (mid boot stage, flag leaf sheath) were susceptible to 2, 4-D. Khan et al. [46] supported that application of 2,4-D at later stages of the wheat development reduced the yield. Recently, Olszyk et al. [47] reviewed the side-effects of various herbicides on different non-target terrestrial plants. The herbicide could be transformed into mutagenic or carcinogenic agents by herbs or vegetables, which are the first living beings in the food chain [48]. Protic et al. [49] reported that 2, 4-D in amount of 1.0kg/ha reduced wheat plant structure upto 18.6%. 2, 4-D application on wheat seedlings reduce the number of plants, biomass and grain yield [49]. The 2, 4-D induced chromosome exchange in immature embryos of wheat species and suggested the genotoxicity of the herbicides [50]. The earlier work indicates that the application of 2,4-D at emergence (0-72 h treatment) to earlier seedling stage (3-5 leaf stage), boot stage and jointing stage to soft dough stage caused toxic effects on germination, cytological abnormalities (inhabitance of cell division and meristematic cells, chromosome aberrations), physiological abnormalities (enzymes, proteins and nucleic acids), and morphological parameters abnormalities (unfolded leaves, less tillers, reduced plant height, delay maturation, scattering of heads, sterility of reproductive structure and reduced grain yield). The results suggested that 2, 4-D suppress the overall growth of the wheat plant. The abnormalities suggested by different workers in different years were supported by the Kumar and Singh [51], Kumar [52], Kumar et al. [53] and Kumar (Unpublished Thesis) [54].

The illustrations shown above supports the work carried out in wheat varieties during 2007-2010 at the Botanical Garden of Banaras Hindu University, Varanasi. The root retardation at juvenile stage or seedlings of wheat could be effected by seed treatment at 72 h with 2, 4-D [51]. The side effects of seed dressings were more characterized on the wheat varieties with a short vegetation period, both in the intensity of germination and yield production [51-53]. The application of 2, 4-D (400 to 1200 ppm concentrations) showed the depressing effects on morphological parameters of wheat [53-54]. The 2, 4-D sprayed on the wheat plant at jointing stage reduces the overall growth of the crop productivity [53-54]. The deformities like scattered heads and irregular spikelets indicate the effect of herbicide on the cytoskeleton microtubule of the cell. The fundamental role of cytoskeleton in cell morphogenesis and intracellular movement is the key to understand the plant growth and development. The appearance of distinctly club shaped or swollen structure in the root tip of seedlings suggest the loss of cortical microtubules, which leads to root clubbing in the zone of root elongation. But the action of 2, 4-D has modified the microtubular assemblies in mitosis, apart from the malfunctioning of the mitotic spindle poles producing different chromosomal abnormalities [52]. Chromosomal disturbances induced by 2, 4-D indicates the genetic damage in wheat [52]. A significant reduction in mitotic division and morphological parameters indicate the mitodepressive action of the herbicide and its interference with normal cell cycle [52]. The application of 2, 4-D has shown the depressive effect on the protein and carbohydrate synthesis of the wheat seedlings [54].

The observations showed that the effects of 2, 4-D depends on the applied doses and growth stages like seedling and boot stage. The application of herbicide showed the mild resistant in wheat varieties slowly. Again, all the observations support the earlier findings of different workers in different years in the wheat plant.

Much effort has been directed toward studies of the effects of method and time of application of 2, 4-D on morphological, physiological, biochemical, histological and cytological response of treated plants. The indiscriminate use of the herbicides in agriculture and the increase of pollution in ecosystems due to industrial development justify the evaluation of the chemicals.

CONCLUSION

The use of herbicide 2, 4-D and its impact on crops, organisms and human health, a rapid multiplication could be practiced by direct plant regeneration in large quantities by micropropagation [55]. Also, physiological side effects of 2, 4-D on different varieties should be continuously tested for purposes of both breeding and improvement of technology. Since the results may influence large scale field application of the 2, 4-D, the analysis of variety specific effects may be of importance for management practice as well [44]. Taking into the consideration that the main and additional activity of the 2, 4-D works simultaneously during the cropping, it seems to be reasonable to seek their resultant effects for each variety of wheat tested [44]. Their potentialities and sensitivity could be utilised for screening the mutants, which may be tremendous agronomic importance. The choice of best herbicide, proper time of application and proper dose is an important consideration for lucrative returns [56].

The inconsistencies may be partly due to interaction effects with environmental conditions. The Allium test was the very good plant bioassay for chromosome damage both in mitosis and meiosis. It can be used for somatic mutations induced by chemicals and radiations. The disadvantageous side effects of the herbicide manifested themselves in simple visual symptoms (head deformation, leaf burning) and in the change of certain production characteristics such as plant height, number of heads, thousand grain weight and yield decrease of different varieties. The higher concentrations (800 and 1200 ppm) of the herbicide may become mitostatic, cytotoxic and clastogenic in this crop [52]. The repeated use or spray in crop field may produce polyploids in this crop as reported earlier. According to U. S. Environmental Protection Agency (EPA), 2, 4-D kills plants by increasing three characteristics of the plant. The three characteristics include the plasticity of the cell walls, the amount of proteins being made in the plants, and the amount of ethylene being produced by the plant [57]. The effect of these changes is to cause cells to divide and the plant to grow uncontrollably. The end result is that the tissues of plant are damaged and death occurs [58].

The situation of environmental changes mainly originate from anthropogenic activities are being responsible for affecting plant growth condition. Since plants are sessile organisms and have limited mechanisms for herbicide application avoidance they need flexible means for acclimatization to changing environmental conditions. Hence in order to improve a plant protection, this kind of researches may be fruitful in understanding of mechanisms contributing to effect of herbicides on plant system.

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