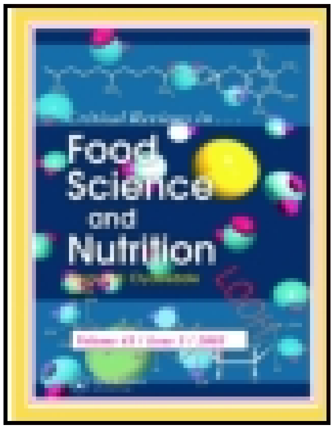

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Selective effect of pesticides on plant - a review

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SELECTIVE EFFECT OF PESTICIDES ON PLANT - A REVIEW

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ABSTRACT

This review represents systematic and integrated picture of pesticide exposure to plant and its effect on growth and metabolism. Decades ago, agrochemicals were introduced aiming at enhancing crop yields and protecting crops from pests. Due to adaptation and resistance developed by pests to chemicals, every year higher amounts and new chemical compounds are used to protect crops, causing undesired side effects and raising the costs of food production. Biological chemical free agriculture is gaining also more and more support but it is still not able to respond to the need for producing massive amounts of food. The use of agrochemicals, including pesticides, remains a common practice especially in tropical regions and South countries. Cheap compounds, such as DDT, HCH and Lindane, that are environmentally persistent, are today banned from agriculture use in developed countries, but remain popular in

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developing countries. As a consequence, persistent residues of these chemicals contaminate food and disperse in the environment. Therefore, the thrust of this paper was to review the application of pesticides effect early from germination to growth of the plant, leading to alteration in biochemical, physiological and different enzymatic and non-enzymatic antioxidants which ultimately affect the yield and resulted in residues in plant, vegetables and fruits.

Key words: Pesticide; Growth; Agriculture; Crop.

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1. INTRODUCTION

The use of pesticide is as old as human civilization in fact when human being started the agricultural activity for the sustainable life. In ancient times, the first intentional use of a pesticide dates back to 2500 BC when the Sumerians rubbed foul smelling sulfur compounds on their bodies to control insects and mites. The use of a wide range of chemicals to destroy pests and weeds is an important aspect of agricultural practice in both developed and developing countries. Although since ancient times there has been a major changes occurred as a result we get more elaborate molecule to tackle our agriculture produce safety, which has led to widespread concern over the potential adverse effects of these chemicals on human health. It is clear that the possibility for exposure to pesticides is greatest among farm workers. Also, it is exceedingly plausible that less controlled and regulated uses of pesticides may offer the greatest opportunity for exposure to toxicologically significant quantities. The demand for pesticide products and the concentrations that they make towards agricultural efficiency are clear but the volume of production indicates that the potential for misapplication and accidental exposure is great. It is estimated that of the total amount of pesticides applied for weed and pest control, only a very small part (<0.1%) actually reaches the sites of action (Pimental, 1995), with the larger proportion being lost via spray drift, off-target deposition, run-off, photodegradation and so on. However the difference in translocation and absorption of pesticides can't be attributed to grain resistance as reported in sorghum (Joy, et al., 2013). Unintended exposure to pesticide can occur during their manufacturing, formulation and application or from environmental residues after application. Indiscriminate and injudicious use of chemical pesticide in agriculture has resulted in several associated adverse effects such as environmental pollution, ecological imbalance, pesticide residues in food, fruit, vegetables, fodder, soil and water, pest resurgence etc.

Today synthetic chemical contamination is pervasive and global. With pesticides that have a highly acute toxicity but are readily metabolized and eliminated, the main hazard lies in acute, short-term exposures. With others that have a lower acute toxicity but show a strong tendency to accumulate in the body, the main hazard is connected with long-term exposure, even to comparatively small doses. Other pesticides that are rapidly eliminated but induce persistent biological effects also present a hazard connected with long-term, low-dose exposures. Adverse effects may be caused not only by the active ingredients and the associated impurities, but also by solvents, carriers, emulsifiers, and other constituents of the formulated product. United Nations environment protection (UNEP) reported that nine of the twelve most unwanted persistent organic pollutants (POP's) are pesticides used in agriculture crop and for public health vector control programme. This review attempts to describe several aspects of the selective effect of pesticides application on plant, focusing on germination, growth and development, alteration in biochemical pathways and some antioxidant enzymes, yield and pesticide residue in crop and also to establish the dose range in which benefits in terms of quality and yield of the crop could be obtained.

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2. PESTICIDE EFFECT ON GROWTH AND METABOLISM OF PLANTS

All pesticides are designed to kill or otherwise control specific plants or animals, so a great deal is known about the acute biological effects of these chemicals on their target organism. The use of agrochemicals entails both benefits and potential risks. These benefits are balanced by an increased risk of phytotoxicity, since treated seeds are often exposed to significantly higher chemical concentrations than occur in foliar treatments applied to established plants. Pesticides control or kill plants through a variety of mechanism, including the inhibition of biological processes such as photosynthesis, mitosis, cell division, enzyme function, root growth, or leaf formation; interference with the synthesis of pigments, proteins or DNA; destruction of cell membranes; or the promotion of uncontrolled growth (William, et al., 1995). Application of pesticide can effect early from germination to growth of the plant, leading to alteration in biochemical, physiological and different enzymatic and non-enzymatic antioxidants that ultimately affect the yield and resulted in residues in plant, vegetables, fruits, and different non-target organisms.

2.1 Germination

The adverse effects of pesticides on seed germination have been studied by several workers. Rajashekar, et al., (2012) studied the abiotic stress i.e pendamethalin in *Zea mays* L. cv NAAC-6002 and found seed germination in control was maximum (95%) where as the germination percentage decreased drastically in the treated sets with increasing concentration of pendimethalin. A severe decrease of about 69% was observed at high concentration of pendimethalin i.e 10.0 ppm which may be attributed to the adverse effect of the herbicide on degradation and mobilization of seed reserves. Recently Moore and Kroger (2010) studied the

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effect of three insecticides and two herbicides (combined and single treatment) on rice seedling germination based on 4 day exposure. Among the insecticides used, fipronil proved to be a lowest (76%) seed germination in compare to control (80%) where as other insecticide diazinon proved better germination (85%) even with respect to control. Mixture of herbicide atrazine /metalachlor proved to be the better germination rate (81%) than singly applied herbicide atrazine (72%) in the rice seedlings. A reduction of 64% in germination of *Salsola iberica* seed from plants treated with chlorsulfuron at 17.05 and 26 g ha^{-1} and paraquat at 560 g ha^{-1} has been reported by Frank and Ralph (1987). A handful of recent studies have examined pesticide effects on germination of various crops. Devlin and Cunningham (1970) have reported the adverse effects of alachlor and propachlor herbicides which reduced the germination of *Hordeum vulgare* L. by interfering with the related metabolic activities. Similarly Schultz, et al. (1967) and Nehru, et al. (1999) observed the inhibitory effect of herbicide pendimethalin and trifluralin on seed germination and early growth in crop *Vigna radiata* L. and *Zea mays* L. respectively. Hirase and Molin (2002) studied a comparison of herbicidal activity effects on germination and seedling growth of *Oryza sativa* L. and *Hemp sesbania* L. Paraquat, 2,4-D, glyphosate, and bromacil toxicity in *Oryza sativa* L. seed was studied by Wang (1994) whereas 4-day exposure of fipronil at 2,000 mg L^{-1} on rice significantly impaired germination (Stevens, et al., 1999). In the experiment of Kintner and Aldrich (1984) which applied sublevel rates of chlorosulfuron to *Abutilon theopbrati* Meidc. at flower bud formation and found that seed germination was reduced. Glyphosate and chlorsulfuron reduced seed germination of *A. theopbrasti* when applied at different stages of weed growth (Biniak and Aldrich, 1986). The use of chlorimuron and imazaquim at 0.28 kg ha^{-1} in *Cassia obtusifolia* L. at early bloom and early fruit stages produced seeds incapable of emergence (Isaacs, et al., 1989). Reduction in the germination of *Galium spurium* L. and *Thlaspi arvense* L. by subnormal doses of tribenuron-methyl (1/8, ¼ and 1/2 of normal field dose) was reported by Andersson (1994). A significant reduction in the viability of seeds after bentazone application to *Xanthium strumarium* L. was investigated by Zhang and Cavers (1994). Glyphosate at 0.44, 0.88 and 1.76 kg a.i ha^{-1} applied 5 and 10 days after anthesis (DAA) significantly suppressed germination of *Avena fatua* seed with 1.76 kg a.i ha^{-1} being the most effective rate, when applied to plants 15 DAA, only the highest rate significantly affected the overall germination (Shuma, et al., 1995). In the experiment by Anderson (1996), a pot trial of three broad-leaved species at five growth stages and two herbicides at four dosages, found varying effects on seed germination. Hald (1999) noted that *T. arvense* L. and *Sinapis arvensis* L. seeds from unsprayed control had a high germination rate, but the proportion of seeds germinating was highest at low dosage (1/16) of Isoproturon. Several workers have described the effects of pesticides on germination which is represented in **Table 1**.

2.2 Growth and Development

Growth and development in crop plants do not proceed at constant or fixed rates through time. Development progress through the life cycle of a plant leads to growth, which is the product increase in the size of organs and the accumulation of the dry matter (biomass), firstly as sugar, then as structural and storage materials in leaves, stems and fruits (Jan, et al., 2012). However, plant is influenced by several exogenous and endogenous factors, genetic, nutritional, environmental and hormonal conditions. Plant growth analysis is a necessary step for the understanding of the plant performances and productivity which reveals different strategies that

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plant follows to survive in conditions where certain factors are limiting. In the experiment of Stevens, et al., (2008), Imidacloprid has been evaluated as a seed treatment on crops such as wheat and barley generally without any phytotoxicity or adverse effects on plant growth being observed. Conversely, Imidacloprid seed treatment has been reported to adversely affect the germination and/or early growth of several crops including leek, white cabbage and sweet corn. When treated seed was planted out and the seedlings assessed 9 days later, there were generally no significant differences in shoot length and root system, dry weights between control and treated plants. Where differences were significant, growth appeared to be stimulated rather than impaired by imidacloprid treatment. Growth enhancement occurred after exposure to imidacloprid concentrations of 500-1000mg AI $L^{-1,}$ but not 2000 AI L^{-1}, the highest concentration evaluated. When imidacloprid exposure was limited to a brief period at either initial seed wetting or immediately prior to sowing, germination and / or subsequent plant growth was unaffected. Other works by Mishra, et al., (2008) showed that high concentration of insecticides dimethoate reduced the growth of root and shoot length. The reduced root growth following high concentration of dimethoate treatment was more pronounced than in shoot which was probably due to greater accumulation of dimethoate in root as it was in direct contact with pesticide. Similar observations have also been made on *Glycine max* L. by Murthy, et al., (2005). Nearly complete inhibition in growth with high concentration of monocrotophos was reported by Saraf and Sood, (2002). Treatment of maize with the recommended field dose of rimsulfuron, imazethapyr, alachlor, atrazine and fluometuron significantly reduced the magnitudes of increase in shoot fresh and dry weight of 10 days old maize seedlings during the following 12 days. This trend consistently augmented by fluometuron, atrazine and alachlor during the whole period but appeared to be nullified by the 5th day of treatment with rimsulfuron and imazethapyr (Nemat Alla, 2007). The herbicide fusillade (Fluazifop-p-butyl) is actively taken up by plants and translocated throughout the plant. The compound accumulates in the actively growing regions of the plant (shoot, root rhizomes, stolons of grass) where it interferes with the plant cell's ability to produce energy and cell metabolism in susceptible species. In plants, fluazifop-p-butyl is rapidly broken down in the presence of water to fluazifop-p (Extoxnet, 1996). Fluazifop-p-butyl kills annual and perennial grasses, but does little or no harm to broad-leaved plants (dicots). It kills by inhibiting lipid synthesis (lipids are necessary components of cell membranes), particularly at the sites of active growth. There is several other reports indicated reduction in growth of several plant species after the application of these herbicide groups (Hassan and Nema Alla, 2005). The reduction in plant growth could result from varied disturbances in certain processes by the herbicide e.g. those related to nitrogen metabolism and photosynthesis (Nadasy, et al., 2000). There is one contact herbicide called Paraquat, which acts rapidly by causing the plant to bleach and wilt within a few hours of application (Ismail, et al., 2001). Paraquat treatment on *Triticum aestivum* L. especially the highest PQ concentration (60 µM), caused desiccation of leaves. The leaves of wild wheat genotypes showed approximately 26% RWC, while the leaves of Harran-95 remained at 44% RWC, after application of 60 µM PQ (Ekmekci and Terzioglu, 2005). In the experiment of Basantani, et al., (2011), there was a general decline in germination percentage, fresh weight and root length of the two *V. radiata* varieties after glyphosate (10 mM) treatment. It has been earlier reported that preharvest application of glyphosate in pea reduced seed germination, seedling emergence and shoot fresh weight (Baig, et al., 2003). Glyphosate has also been known to reduce leaf dry matter

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accumulation in *Phaseolus vulgaris* L. (Brecke and Duke, 1980). Many studies have been carried out to evidence the effects of variable doses of different pesticides on growth and development attributes (**Table 2**).

2.3 Biochemical and physiological effects

Previous studies demonstrate that the accumulation of pesticides by plant affected the plant growth and caused the metabolic disorders (Sharples, et al., 1997). For example, chlorotoluron blocked the higher plant photosynthetic electron transport (Fuerst and Norman, 1991) and disrupted PSII reaction centre (Barry, et al., 1990). There is one uracil type herbicide that blocks both the Hill reaction and photosystem II in the photosynthetic pathway. Terbacil was used on fruit trees as a method to limit photosynthesis can cause thinning (Del Valle, 1985). Others have used terbacil as a tool to investigate the damage thresholds (Disegna, 1994). Propanil, which is highly selective post-emergence herbicide, is extensively used to control grass weeds in several different crops. It belongs to class of anilides, and is a photosynthetic inhibitor which inhibits photosystem II in chloroplasts (Devine, et al., 1993).The fungicide captan application resulted in reduction of chlorophyll a, b as well as total chlorophyll and carotenoid contents in pepper leaves but the recommended dosage resulted in increase in chlorophyll a and carotenoid contents as compared to higher dosages and control. Reduction of these contents was higher at the higher dosages of the fungicide (Tort and Turkyilmaz, 2003). In the same study the application of captan in the recommended dosage of 2.5 g l^{-1} increased the amount of carotenoids and internal ABA concentrations of leaves. Sivakumaran and Hall (1978) stated that in cases where environmental conditions negatively affect plants, the amount of abscissic acid (ABA), a hormone hindering the metabolic activity in the plant, increases. Steward and Krikorion (1971) determined that the fungicide Antrakol, inhibited photosynthesis in *Nicotiana tabacum* L. The decrease in photosynthetic pigment substances may also cause decline in the nutrition value of the pepper plant, considering the fact that the vitamin synthesis takes place in chloroplast. The effect of herbicide treatments on chlorophyll content in foliage at flowering (45 DAS) consistently declined with increasing rates of herbicides but was significant ($p<0.05$) only at 400 µg active ingredient (a.i) kg^{-1} of atrazine, isoproturon and metribuzin. In contrast, 200 µg a.i.kg^{-1} of isoproturon and sulfosulfuron stimulated the chlorophyll content in fresh leaves of green gram (Khan, et al., 2006). The reduction in photosynthetic pigments could be due to inhibition in photosynthesis. For instance, metribuzin inhibits photosynthesis by blocking electron transfer from compound Q to plastoquinone in photosystem II (Fedtke, 1982) and hence prevent the reduction of $NADP^+$ required for CO_2 fixation. Further, the pigment deficiency in the foliage of green gram plants may be caused by photo bleaching (Barry, et al., 1990). Moreover, the decreased supply of photosynthate to the roots due to toxic action of atrazine and metribuzin and the direct effects of these herbicides on the growth of *Bradyrhizobium* in vitro might have resulted in the reduction of functional symbiosis. The data from this study thus supported the concept that the detrimental effect of atrazine and metribuzin is primarily bacterium mediated that resulted in the indirect effects on nodulation and yield (Alonge, 2000). In the study of Khan, et al., (2009), nitrogen and protein contents of grain were not affected significantly while nitrogen uptake showed significant variation. This study also revealed that although the insecticide pyrifos proved effective in managing pod borer damage yet it was harmful to chickpea *Rhizobia* in the crop rhizosphere by decreasing its survival significantly. So, the crop sprayed by proofs for pod borer control, increased the grain yield at the cost of decreased nitrogen fixing capability of the crop by suppressing the rhizobial population in the rhizosphere and spray before pod formation is very harmful thus resulting in decreased natural nodulation in the crop. Musarrat and Haseeb (1999) attributed this decrease in nodulation to the protection of rhizobium recognition sites by extensive application and accumulation of agrichemicals (paraquat) on the root surface of legumes. This is exactly like the side effect of antibiotics. Kaushik and Inderjit (2006) found that mung bean grown in soil treated with herbicides showed continuous decrease in chlorophyll (chl) content with increasing dose of herbicide and concluded that most of the biochemical symptoms associated with pesticide toxicity were chl degradation and activation of oxidation process. Apart from antennae function, carotenoids (Car) also act as natural defence against photodynamic damage caused to photosynthetic apparatus under stress condition. Significant reduction in Car contents was reported in other plants under pesticide stress (Klennin, 1974; Burns, et al., 1971; Fujii, et al., 1977). A concentration dependent inhibition in photosynthetic oxygen yield and CO_2 fixation were adversely affected by dimethoate which could be explained on the basis of direct effect of dimethoate on various sites of photosynthetic electron transport chain (Mishra, et al., 2008). In the same experiment, photosystem II and whole chain activities were found to decrease in chloroplasts at all concentrations of dimethoate. Direct exposure of chloroplast with growth stimulatory dose (50 ppm) of dimethoate even caused appreciable inhibition in PSII and whole chain activity that possibly resulted due to damage caused at oxygen evolving complex (the most labile component) as evident from complete recovery of PSII activity in presence of artificial electron donors. Further, the interruption in electron transfer ability was extended to PSII

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reaction centre (P_{680}) and plastoquinone site (reducing site of PSII) with excess dimethoate (100 and 200 ppm). Increase in proline content under paclobutrazol in *Eruca sativa* seedlings were observed by Mathur and Bohra (1992). Similarly, ABA increased the proline content in *Phaseolus vulgaris* L. (Mackey, et al., 1990). Triadimefon treatment in *C. roseus* increased the protein, amino acid, and proline and glycine betaine contents in the leaves, stem and root (Jaleel, et al., 2007a). Glycine betaine accumulation results from the oxidative stress induced by the fungicidal application; it is helpful in the stimulation of tolerance mechanism (Jaleel, et al., 2007a; Sankar et al., 2007). The increase in the protein content has been previously described in *Echinochloa farmentacea* (Sankhla, et al., 1992) and in *Brassica carinata* (Setia, et al., 1995) plants treated with paclobutrazol and uniconazole respectively. Similarly uniconazole treated *Phaseolus vulgaris* L. (Mackay, et al., 1990) and penconazole induced a moderate increase in amino acid in higher plant (Radice and Pesci, 1991). Plants respond to a variety of stresses by accumulating certain specific metabolites like amino acids (Jaleel, et al., 2007; Manivannan, et al., 2007). It may perhaps provide extra protection to plants against oxygen radical damage arisen from abiotic stresses (Jaleel et al., 2007a). Different workers have described the effect of pesticide on various physiological and biochemical processes as represented in **Table 3**.

2.4 Oxidative stress and antioxidative defense system

Environmental stresses may prompt various types of physiological response and oxidative damage in plants. The pollutants in the environment are able to induce the intracellular over-production of reactive oxygen species (ROS), thus damaging plant cells. It is known that the reaction of such radicals with macromolecules particularly lipoprotein caused peroxidative damages more rapidly and is evident from membrane lipids destruction (Jan, et al., 2012a). Triazoles are a group of compounds which have fungicidal as well as plant growth regulatory properties. Electrolyte leakage and lipid peroxidation were inhibited by the triazoles treatment in carrot plant when compared to control (Gopi, et al., 2007). To protect the seedling from the deleterious effect of these stresses some enzymes such as catalase (CAT), peroxidase (POD), ascorbate peroxidase (APX), glutathione reductase (GR) and superoxide dismutase (SOD) are activated to scavenge free radicals and peroxides (Prasad, et al., 2005). A strong correlation between anti-oxidant content and fungicide carbendazim concentration applied as soil drench at 0, 5, 50, and 100mg kg^{-1} was observed. The changes in the activity of SOD, CAT, GPX enzymes were measured in roots, stem and leaves of cucumber were observed in cucumber cotyledons than the older leaves. It was concluded that cotyledons might play an important role for adaptation as the carbendazim concentration increased, and the ability of mature cucumber to maintain a balance between the formation and detoxification of activated oxygen species appeared likely to enhance the plants sampling at cotyledons phase (14 days) and fluorescence phase (56 days) (Zhang, et al., 2007). The induction protein accumulation in roots of cotyledon phase under carbendazim treated plants may attributed the properties cytokinins of carbendazim (Skene, 1972). Zhang, et al., (2001) determined that rice seedling in the presence of herbicide mefenacet showed increased activities of SOD and CAT. Wu and Tiedemann (2002) results indicated that the fungicide azoxystrobin and epoxiconazole significantly enhance SOD and CAT activity. It was also demonstrated that paraquat applications resulted in increased membrane permeability and MDA contents together with a decrease in unsaturated fatty acids contents, indicating enhanced lipid peroxidation reactions (Chang and Kao, 1997). SOD leads to the overproduction of H_2O_2 to eliminate the toxicity of $O2^{-\cdot}$. APX is the first enzyme detoxification of cellular H_2O_2 through the activity of the ascorbate-glutathione scavenging cycle. On the other hand, the last enzyme of ascorbate-glutathione cycle, GR, catalyses the NADPH-dependent reduction of oxidized glutathione (Ekmekci and Terzioglu, 2005). It is the rate limiting enzyme in the H_2O_2 scavenging cycle (Asada, 1999). Casino, et al., (1999) and Slooten, et al., (1995) have reported that GR was not significantly correlated with PQ-induced damage in spite of its increased activity and played limited role in the protection against photooxidative stress. In the experiment of Yoon, et al., (2011) Paraquat application is expected to affect foremost the antioxidant expression in the thylakoid membrane where PS1 is located. Although the isoforms were not characterized here, and each antioxidant was measured as a total value instead of specific to the thylakoid membrane, a significant change in the antioxidant level (or activity) in response to paraquat application is assumed to emanate primarily from isoforms located in the thylakoid membrane. The paraquat effect may cascade to other isoforms as the physiological damage expands to other organelles and organs. Elevated activities of APX and AsA in the youngest leaf, in addition to high leaf wax content, most likely contributed to higher tolerance to paraquat in young leaves than old ones. With reduced absorption of paraquat owing to high wax content and increased detoxification of herbicide molecules entering the leaf cells, herbicide damage in young leaves would be less. Tolerance to paraquat in some plants has been correlated with the scavenging capacity of superoxide ions and often with the SOD activities (Bowler, et al., 1991; Camp, et al., 1994). However, in squash, SOD activity in the oldest leaf which was more susceptible to paraquat, was generally higher than in leaves 2, 3, and 4. This indicates that in squash, SOD is not critical for paraquat detoxification or in protecting the plant from oxidative stress. A similar observation was reported in barley where SOD expression in leaves was not responsive to oxidative stress (Casano, et al., 1994). However, other antioxidative enzymes were induced by oxidative stresses. This trend was also observed in squash, at least with respect to AsA. Chloroplastic APX, the key enzyme responsible for scavenging H_2O_2 generated in chloroplasts, is paradoxically sensitive to H_2O_2 (Miyake and Asada, 1996). The reduced injury in younger leaves is partially due to higher antioxidant activity in younger leaves than in old ones. Other researchers have suggested that enhanced activities of SOD, CAT, and GR were associated with natural paraquat resistance in perennial ryegrass (Harper and Harvey, 1978). Such natural, enhanced enzyme activities neutralize the various toxic forms of oxygen, thus, reducing lipid peroxidative reactions. To illustrate, application of ascorbate and glutathione before paraquat treatment protected cucumber leaves from paraquat injury (Kuk, et al., 2006). However, Turcsanyi, et al., (1998) reported that the oxygen radical detoxifying pathway with SOD and the enzymes of the ascorbate-glutathione cycle or CAT alone do not explain the high level of paraquat resistance in *Conyza canadensis*, nor is resistance to paraquat always directly related to enhanced antioxidative protection (Bhargava, 1993). Thus, other mechanisms may also contribute to paraquat tolerance in different leaves. There is indication that tolerance mechanisms for paraquat are shared by other herbicides having the same mode of action such as diquat. However, these mechanisms do not confer tolerance to other membrane-disruptor herbicide, such as acifluorfen, which inhibits the protoporphyrin oxidase enzyme and causes peroxidation of membranes by another pathway. In the experiment of Basantani, et al. (2011), the activity of two antioxidant enzymes, CAT and POD, was measured after glyphosate treatment. CATs are involved in the metabolism of oxidative stress causing herbicides and

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protect plants from the stress generated by herbicide overdoses. CATs involved in herbicide tolerance, or an increase in CAT activity during herbicide exposure, have been reported from several plant species (Jung, et al., 2006; Jung, 2003; Radetski, et al., 2000). In the same experiments CAT activity was found to increase after glyphosate treatment. However, the fold increase was different in the two varieties. The activity increased by 1.9- fold at 4 mM as compared to control in PDM11, and by 1.6-fold in PDM54. A few earlier reports too have shown an increase in CAT activity in *V. radiata* plants after herbicide exposure. A herbicide 2-benzoxazolinone (BOA) was found to cause oxidative stress in *V. radiata* plants, which responded by an increase in the activity of ROS scavenging enzymes like CAT and SOD in the root and leaf tissues (Batish, et al., 2006). Sergiev, et al., (2006) demonstrated that CAT activity was increased after 6 and 10 days of glyphosate application in maize plants. POD upregulation after herbicide exposure has been demonstrated in wheat (Wang and Zhou, 2006), tobacco (Yamato, et al., 1994), and many other plant species. Different workers have described the effect of pesticide on the expression of anti-oxidant enzymes as represented in **Table 4.**

2.5 Yield

The pod and seed yield losses caused by the pod borers and pod-sucking bugs are rather devastating. Though little work has been conducted regarding pod loss due to pod borers and other pod feeding insect pests, greater attention has been paid to seed yield losses experienced because of the insect borers in most grain legumes. The difference in pod damage is worth highlighting because damaged pods may not produce seeds or if so the seeds may be of a low quality and sometimes may not be viable (Mugo, 1989). Thus, the pesticides used provided a good protection cover against pods infestation by the pod borers paving way for better seed yield.

The foliar application of chlorpyrifos in mungbean seedlings has been worked by Parween, et al., (2012). In this study 0.3 mM chlorpyrifos treatment increased the yield attributing characters viz. highest number of pods, number of seeds per plant and dry seed weight. Increased plant height, larger leaf area per plant and more uptakes of nutrients would have increased the translocation of photosynthates which, in turn, resulted in more number of pods per plant. Chibu, et al., (2002) reported that application of chitosan at early growth stages increased plant growth and development, thereby increased seed yield in rice and soybean. Similar results were also observed by Boonlertnirum, et al., (2005) in rice and Rehim, et al., (2009) in maize and bean. In the experiment of Amengor and Tetteh (2008), the effect of increasing rates of application of lindane (156.0, 244.0 and 312.0 g ha^{-1}), unden (propoxur) (125.0, 187.5 and 250.0 g ha^{-1}), dithane and karate (166.6, 209.8 and 333.3 g ha^{-1}) on garden eggs, okra and tomatoes was studied which revealed yields of garden eggs were suppressed by all the rates of lindane applied. In tomatoes, lower rates of lindane increased yields whereas the higher rates suppressed yields lower than the control. In okra yields were higher than the control at all levels of lindane applied though yield increments were low. Unden application had the highest effect on garden egg yields followed by tomatoes and least on okra. In the garden egg and tomato treatments, increasing concentration of unden resulted in decreasing yields though yields were higher on the control plots. More scientists have worked on pesticide effect on yield which is represented in **Table 5.**

2.6 Residues in vegetables and fruits.

It is a well known that injudicious and indiscriminate use of pesticides lead to high residue levels in food. Even small quantities of these residues present in food lead to high levels in the body fat when these food stuffs are taken over long period of time. Pesticide residues in food have historically lagged far behind many comparable hazards as a cause for public health concern and action. Pesticide residue contaminating food is the problem focused worldwide because of its direct implications on human health and international trade (Sanborn, et al., 2004). Reliable residue analysis data resulting from monitoring programs in foods, even if limited, may be of great value indicating the possible risks of pesticide exposure on human health and on international trade (DAF and FSAI, 2006). The Maximum Residue Limits (MRLs) as food standards differ widely for the same pesticide on the same commodity between countries as well as with the international Codex Committee standards (Codex, 2010). However, scientists cannot say for sure that there is ever a “safe” level of pesticide residues in food because many of the chemical messengers in our bodies function at precisely minute quantities of ppm or even ppb (Boobis, et al., 2008). Shinde, et al., (2012) studied that the Cypermethrin were applied separately in three different concentrations i.e. 50ppm, 75ppm, 100ppm on okra crops and the residue were determined 0,1,3,5, 7,9,11,13,15,17,19 and 21 days after application. The results indicate that the residue below the detectable level were found after 17 days. The experiment of Akinloye, et al., (2011) revealed that in all the randomly selected samples tested, PQ residues detected were below the maximum residues limits (MRLs) of 0.5 mg/kg set by the UK pesticides levels in crop foods and feedstuffs (Regulation, 1994; Statutory Instrument, 1985). The experiment of Dhas and Srivastave (2010), the initial deposit of Carbaryl on brinjal fruits were of 11.47 ppm from 0.2 percent Carbaryl spray and dissipated to 9.93 ppm within one day after treatment recording thereby a decrease in residue to about 13.40 percent. Deshmukh, et al., (1972) reported only 5.4 ppm of initial deposit, which might be due to the use of lower dosage. Kavadia and Shanker (1976) however, reported a less deposit on tomato fruits from 0.25 per cent carbaryl application. This could be attributed to the fact that the insecticide was applied only once. When the treated fruits were collected after 10 days and analyzed, 1.87 ppm of residue was observed indicating thereby 83.74 percent loss which further went down to 91.69 per cent after 15 days. The residue reached below tolerance level (FAO/WHO, 1972) after 6 days of application during the present study. The same waiting period was also reported by Kavadia and Shanker (1976). The fruits can, therefore, be considered as fit for human consumption after 6 days waiting period. The complete dissipation was recorded after 25 days of spray. Similar results have also been reported by Deshmukh and Singh (1975) while studying dissipation of Carbaryl and Malathion from okra fruits. In the experiment of Abd Allah, et al., (1993), tomatoes treated with pirimiphos-methyl could be marketed one day after application, after 8 days when fruit is treated with profenofos. Green beans could be consumed safely 4 and 11 days after spraying with pirimiphos-methyl and profenofos, respectively. Miinute amount (0.02 ppm) of profenofos were detected in pods of cowpea 15 days after spraying while pirimiphos-methyl was undetectable in the whole pods after 10 days (Soliman, 1994). The level of pirimiphos – methyl or chlorpyrifos-methyl residues on broad bean seeds was found to be with in the MRL's 5 days after application, while exceeding the MRL's on tomatoes after 5 and 7 days of application , respectively (Radwan, et al., 1995). The waiting period of 21 days after application of pirimiphos – methyl on grapes is enough to reduce residues to below the MRL's (Radwan, et al., 2001). Different level of pesticide residues in different crops has been represented in **Table 6.**

Conclusion and Perspective:

Though the pesticide application represents viable solution to pest control, however indiscriminate use poses threat to target as well as non target crops. The side effects of pesticides therefore have to be considered based on their use and on the agricultural system to which particular pesticide is used. Studies should be implied on effects and persistence of pesticides in crops and is consequent effects on soil microbial flora and associated nitrogen metabolism. Safe alternate methods like development of relatively cheaper biopesticide should be encouraged. More efficient methods have to be developed and validated for dissipation of pesticide residues in food grains. Further, research should be focused for recognition of cell defensins and cell kinases that are triggered in response to pesticide toxicity.

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Table 1. Effects of pesticides exposure on germination of different plant species.

S No.	Plant species	Pesticide used	Class	Dosage	Mode of application	Effect	References
1.	*Cenchrus setigerus* Vahl, *Pennisetumn pedicellatum* Tan.	Chlorpyrifos, Cypermethrin, fenvalerate.	Insecticide	0-100 $mgKg^{-1}$.	Spiked Soil	Significant reduction and delay in seed germination at higher concentrations (75 and 100 mg/kg) of Chlorpyrifos compared to cypermethrin and fenvalerate.	Dubey and Fulekar, 2011.
2	*Cucumis sativus* L., *Zea mays* L.	Paraquat, glyphosate, glufosinate-ammonium	Herbicides.	Paraquat, glufosinate-ammonium at 200, 400, 600 and 800 g a.i. ha^{-1} and glyphosate at 400, 800, 1200 and 1600 g a.i. ha^{-1}	Field plots	Germination rate of the plants were more than 90 percent normal (when compared with those from untreated plots).	Wibawa, et al., 2009.
3	*Triticum aestivum* L. *Vigna radiata* L	Menazon, disulfoton, GS-14254	Pesticide.	Menazon (0-250 ppm), disulfoton, GS-14254 (0-100 ppm).	Seeds treated in petriplates	At certain concentrations these pesticides suppressed germination of these species.	Dalvi, et al., 1972.
4	*Vigna radiata* L.	Bayleton, topsin-M	Fungicides.	0, 1000, 1500, 2000 ppm for 30 min.	Seeds treated in petriplates	Bayleton showed adverse effects on seed germination of vigna radiate as compared to Topsin-M.	Siddiqui and Ahmed, 1996.
5	***Pennisetum americium* (L.) Leeke**	Topsin-M, Dimecron	Fungicide and insecticide.	Topsin-M, Dimecron @ 100, 200, 300 ppm in the ratio 3:1, 1:1, 1:3	Petriplates	Topsin-M used @ 100, 200 and 300 ppm respectively showed 60, 70 and 80% germination of seed as compared to 90 % germination were recorded when seeds treated with 100, 200 and 300 ppm dimecron.	Siddiqui, et al., 1999.
6	*Zea mays* L.	Pendimethalin	Herbicide	0-10ppm	In Hoagland solution	The germination percentage decreased drastically about 69% at higher concentration of pendimethalin. Similarly length of plumule decreased by 77% and the length of radical decreased upto 90% at	Rajashekhar, et al., 2012.

						10 ppm.	

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Table 2. Effects of pesticides exposure on morphological traits of different plant species.

S No.	Plant species	Pesticide used	Class	Dosage	Mode of application	Effect	References
1	*Vigna radiata* L.	Chlorpyrifos	Organophosphate	0-1.5 mM	Foliar	Significant Increase in plant height, number of branches, leaves per plant, total leaf area, plant biomass. Further increase in insecticide level had a negative impact upon all the above parameters studied.	Parween, et al., 2011a.
2	*Triticum aestivum* L.	Chlorotoluron	Phenylurea herbicide	0-25mg/kg	Soil	Root, leaves and biomass were affected. Root tissue affected more than leaves.	Song, et al., 2007
3	*Vigna radiata* L.	Methamidophos	Insecticide	0-1250 mL ha^{-1}	foliar	Increased in plant height, branches $plant^{-1}$, grain pod^{-1}, seed weight, seed yield, @ 1000mL ha^{-1}	Khan, et al., 2006
4	*Solanum tuberosum* L.	Metobromuron, metribuzin and chlomazon	herbicide	28.17, 08.45mg/pot, 07.04ml/pot	spray	Decrease in number of leaves, least changes in shoot length, fresh and dry shoot weight and tuber weight	Dobozi, et al., 2002
5	*Oryza sativa* L.	Imidacloprid	Chloronic-tinyl insecticide	0-2000 mg AI L^{-1}	Seed treatment	No adverse effect on plant growth if applied to pregerminated rice. Continous exposure of seed during germination had more pronounced effects on growth .	Stevens, et al., 2008
6.	*Cicer arietinum* L.	Lorsban,Decis, Pyrifos,Karate, Ripcord	insecticides	875 ml $acre^{-1}$, 200 $mlacre^{-1}$, 1125 ml $acre^{-1}$, 250 ml $acre^{-1}$, 225 ml $acre^{-1}$.	Sprayed at 45 days after planting and at pod initiation stage	Nodulation significantly suppressed after pyrifos treatment. Grain yield was significantly higher after pryrifos treatment as compared to other insecticide tested	Khan, et al., 2009; and Mahmood and Shah, (2003)

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7.	*Oryza sativa* L.	Acetochlor and bensulfuron-methyl	Herbicide	0 – 100 µmol/L	Nutrient solution	Biomass of root and shoot decreased	Huang and Xiong , 2009
8.	*Lens culinaris* L.	Mancozeb	Insecticide	0-0.5%	Seed treatment	Root length, shoot length, biomass, number of leaves, flowers, pods and leaf area increased @ 0.1% and thereafter decreased	Bashir, et al., 2007b
9.	*Withania somnifera* L.	Triadimefon	Fungicide	10 mg L^{-1}	Seed treatment	Shoot length and leaf area reduced but root length got increased	Jaleel, et al., 2008
10.	*Triticum aestivum* L.	Imidacloprid, tebuconazole	Insecticide, fungicide,	0.7 and 1.05g a.i.	Seed treatment	Increase in total grain yield of the wheat crop.	Ahmed, et al., 2001
11.	*Vigna radiata* L.	Atrazine, isoproturon, metribuzin and sulfosulfuron	Herbicide	0-400 µg kg^{-1}	Pre-emergence treated soil	Increase in seed yield, root and shoot length, plant dry weight, number and dry weight of nodule when treated with sulfosulfuron whereas other herbicide showed decrease in the above said parameters	Khan, et al., 2006
12.	*Lens culinaris* L.	Fusilade	Herbicide	0-1.5%	Seed and leaf treatment	Root and shoot groth reduced. Leaf deformations like chlorosis, curling, expansion and asynnetry was observed. Leaf treatment was more sensitive that seed treatment.	Aksoy and Dane, 2007
13.	*Lycopersicon esculentum* Mill.	Fosetyl-Al (aluminium tris-o-ethyl phosphonate)	Fungicide	0-400g/100 L	Seedling	Alteration in morphological structures of tomato pollens.	Cali, 2008
14	*Daucus carota* L.	Hexaconazole and paclobutrazol	Fungicide	0-20 mg L^{-1}	Soil drenching	Fresh and dry weight of leaves and tuber increased under hexaconazole treatment.	Gopi, et al., 2007
15	*Vigna unguiculata* L.	Dimethoate	Organophosphoros insecticide	0-200 ppm	Seedling	Significant decrease under higher concentration in leaf area, shoot and root length, fresh and dry mass of shoot, root and leaf whereas at lower concentration all the above said parameters enhanced	Mishra, et al., 2008

						significantly except root parameter.	
16	*Momordica charantia* L.	Dimethoate	Organophosphorous insecticide	0-200 ppm	Seedlings	Significant decrease under higher concentration in root and shoot length, leaf area, fresh and dry mass of shoot, root and leaf whereas at lower concentration, all the above said parameters enhanced significantly except root parameter.	Mishra, et al., 2009

Table 3. Effects of pesticide exposure on biochemical parameters of different plant species.

S .No.	Plant species	Pesticide used	Class	Dosage	Mode of application	Effect	References
1	*Vigna radiata* L.	Chlorpyrifos	Organophosphat e	0-1.5 mM	Foliar	0.6 and 1.5 mM showed comparatively more toxic to *Vigna radiata* by decreasing nitrate, NR activity, soluble sugar and protein content where as at low concentration (0.3 mM) of chlorpyrifos proved stimulant for same parameter. An increase in soluble amino acid was observed in age and dose dependent manner.	Parween, et al., 2011.
1.	*Triticum aestivum* L.	Chlorotoluron	Phenylurea herbicide	0-25 mg/kg	Soil	Chlorophyll content decreased even at 5 mg/kg. Accumulation of soluble sugars in roots @ 10-25 mg/kg and in leaves @ 15-25 mg/kg	Song, et al., 2007
2.	*Oryza sativa* L.	Acetochlor and bensulfuron-methyl	Herbicide	0 – 100 μmol/L	Nutrient solution	Nitrate content,NR activity, sugar content, protein content, decreased , free amino acid and ammonium content increased under treatment	Huang and Xiong , 2009.
3.	*Medicago sativa* L.	Promet and carbofuran	Insecticide	Promet@ 3L and Carbofuran @ 1, 2 and 3 L / 100 kg seeds	Presowing treatment of seeds	Promet increased NR activity in root and stem and decreased in leaves, In carbofuran, NR activity increased in root, whereas lower activity in leaves as compared to control.	Vasileva and Ilieva, 2007.
4.	*Saccharum officinarum* L.	Methyl viologen	Paraquat herbicide	0-8 mM	Foliar spray	Chlorophyll content and soluble protein concentration was significantly reduced higher than 2 mM after	Chagas, et al., 2008

						48h exposure	
5.	*Lactuca sativa* L., *Phaseolus coccineus* L., *Pisum sativum* L. seeds and leaves	Paraquat, Alachlor and metolachlor	herbicide	0.1 - 2.0 µM of paraquat, 0.2 – 200 µM of Alachlor and metolachlor	In nutrient medium	Chl a, chl b and Car contents decreased	Stajner, et al., 2003/4
6.	*Withania somnifera* L.	Triadimefon	Fungicide	10 mg L^{-1}	Seed treatment	Chl a, chl b and total chlorophyll content increased.	Jaleel, et al., 2008
7.	*Vitis vinifera* L.	Fludioxonil and pyrimethanil	Fungicide	1.2 and 30 mM	Foliar spray	Nitrogenous compounds like total soluble proteins, total free amino acids, free proline and ammonium content accumulated transiently. Leaf water content and carbohydrate levels modified under the both fungicide treatment.	Saladin, 2003
8.	*Hordeum vulgare* L.	Clomazone	Herbicide	0.25 and 0.5 mM	Pre-emergently applied	Reduction in chl a and b , carotenoid content. Increase in chl a/b ratio, lower chlorophyll fluorescence reabsorption.	Kana, et al., 2004.
9.	*Capsicum annuum* L.	Captan	Fungicide	0-7.5 g l^{-1}	Seed treatment	Higher amount of chl a as well as chl a/b ratio and total chlorophyll at 2.5 g l^{-1} than the higher dosewhile chl b and total chl was reduced in all the treated plot. Higher amount of protein , proline and ABA content upto 5.0 g l^{-1}.	Tort and Turkyilmaz, 2003.
10	*Fragaria × ananassa*	Terbacil	Herbicide	0-200 ppm	Spray	Chl a and total chlorophyll reduced but recovery was observed after 4 days. Chl b and P chl content not effected	Makaraci and Flore, 2006.
11	*Triticum aestivum* L.	Paraquat	Herbicide	0-60 µM	Foliar	Loss of chl (a+b), carotenoid content.	Ekmekci and Terzioglo, 2005.
12	*Catharanthus roseus* L.	Triadimefon	Fungicide	0-15 mg l^{-1}	Soil drenching	Proline, protein, glycine betaine and amino acid content increased	Jaleel, et al., 2007a.
13	*Vigna radiata* L.	Atrazine, isoproturon, metribuzin and	Herbicide	0-400 µg kg^{-1}	Pre-emergence treated soil	Sulfosulfuron increase in seed protein and total chlorophyll content	Khan, et al., 2006.

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		sulfosulfuron				whereas other shows depressing effect.	
14	*Daucus carota* L.	Hexaconazole and paclobutrazol	Fungicide	0-20 mg L^{-1}	Soil drenching	Paclobutrazol performed best in terms of anthocyanin, protein, aminoacid, proline, starch and sugar contents whereas hexaconazole enhanced carotenoid. No significant variation in chl a and b between the two fungicide.	Gopi, et al., 2007.
15	*Vigna unguiculata* L.	Dimethoate	Organophosphorous insecticide	0-200 ppm	Seedling	Significant decrease under higher concentration in chl a and b, total chl, carotenoid and chl/car ratio, photosynthetic oxygen yield, photofixation of carbon ($^{14}CO_2$), photosynthetic electron transport activities and photorespiration whereas at lower concentration all the above said parameters enhaced significantly.	Mishra, et al. 2008.
16	*Triticum aestivum* L., *Zea mays* L.	Metribuzin, butachlor and chlorimuron-ethyl	Herbicide	0-20 g ha^{-1}	Seedling	Slightly affected the activities of nitrate reductase (NR), nitrite reductase (NiR) greatly inhibited glutamine synthetase (GS), glutamate synthase (GOGAT). Accumulation of total-N, protein and amino acid.	Nemat Alla, et al., 2008.
17	*Zea mays* L.	Rimsulfuron, imazethapyr, alachlor, atrazine,	Sulfonylurea herbicides	0-2.98 kg a.i. ha^{-1}	Spray	Inhibited the C_4 photosynthetic enzymes like PEPC, MDH, PPDK and Rubisco.	Nemat Alla, et al., 2007.
18	*Vitis vinifera* L.	Flumioxazin	Herbicide	0-100 µM	In nutrient medium	Negative impact on photosynthesis as revealed by a reduction in foliar chlorophyll and carotenoid contents,	Saladin, et al., 2003.

						gas exchanges and alteration in plastid structure. Accumulation of soluble sugar and starch were observed in all organs.	
19	*Oryza sativa* L.	quinalphos, chlorpyriphos, methyl parathion, endosulfan, imidacloprid and deltamethrin	Insecticide	Half of Recommended dose @ 0.10, 0.10, 0.03, 0.10, 0.0035 & 0.0018, 0.0025 respectively	Applied three times @ 10 days interval to potted plant	Biochemical analyses of the rice leaves revealed significantly higher quantities of reducing sugars, proteins and amino acids, but lower amounts of total phenols in leaf sheaths and blades of methyl parathion-, deltamethrin- and quinalphos-treated plants of the two varieties. Chlorpyriphos and endosulfan significantly lowered or did not influence the content of reducing sugars in the leaf sheaths and leaf blades of the plants.	Suri and Singh, 2011.

Table 4. Effects of pesticide exposure on oxidative stress of different plant species.

S.No.	Plant species	Pesticide used	Class	Dosage	Mode of application	Effect	References
1	*Vigna radiata* L.	Chlorpyrifos	Organophosphate	0-1.5 mM	Foliar	Lipid peroxidation rate and proline content increased with 1.5 mM at Day 20 whereas dehydroascorbate, oxidized and total glutathione were increased in 1.5 mM at Day 10. Declined in the content of ascorbate and reduced glutathione levels were observed. Activities of SOD, APX and GR enhanced significantly in all the concentrations at Day 10. Maximum CAT activity was observed at Day 10 in control and declined thereafter.	Parween, et al., 2012a.
2	*Triticum aestivum* L., cv. Mironovskaya 808), *Secale cereale* L., cv. Estafeta Tatarstana, and *Zea mays* L., cv. Kollektivnyi 172MV	TOPIK, EC (active ingredient is Clodinafop-propargyl).	Post-emergence herbicide-(Aryloxyphenoxypropionate).	8–800 μg/L.	Dipping & foliar	Increases in (Lipid Peroxidation) LPO intensity, superoxide anion O_2^- generation, total antioxidant activity (AOA), and catalase (CAT) and ascorbate peroxidase (APOX) activity, although the response by plants was nonlinear and depended on the herbicide concentration and duration of treatment. The highest level of generation of O_2^- was observed in the leaves of maize and winter wheat treated by 800 μg/L CP, both in the short and long-term. As TOPIK concentration increased, so too did LPO and AOA in leaves.	Lukatkin, et al., 2013.
3	*Triticum aestivum* L.	Chlorotoluron	Phenylurea herbicide	0-25mg/kg	Soil	Accumulation of O_2 and H_2O_2 in leaves,resulted in peroxidation of plasma membrane lipids. Proline, SOD, POD, APX activity enced, CAT activity suppressed .	Song, et al., 2007
4.	*Saccharum officinarum* L.	Methyl viologen	Paraquat herbicide	0-8 mM	Foliar spray	SOD, APX, Lipid peroxidation increased	Chagas, et al., 2008
5.	*Withania somnifera* L.	Triadimefon	Fungicide	10 mg L^{-1}	Seed	Non enzymatic	Jaleel, et al., 2008

					treatment	antioxidant like AA, GSH and α- toc content and enzymatic anyioxidant like SOD, POX, PPO AND CAT were increased in all plant parts	
6.	*Cucumis sativus* L.	Carbendazim	Fungicide	0-100 mg kg^{-1}	Soil drench	SOD, CAT increased in roots and leaves and GPX in stem, while in stems, SOD and CAT activities were increased in fluorescence phase and declined in cotyledon phase.	Zhang, et al., 2007
7.	*Lactuca sativa* L., *Phaseolus coccineus* L., *Pisum sativum* L. seeds and leaves.	Paraquat, Alachlor and metolachlor	Herbicide	0.1 - 2.0 µM of paraquat, 0.2 – 200 µM of Alachlor and metolachlor	In nutrient medium	SOD and CAT activity declined in all species. GPX activity in the lettuce seeds was inhibited strongly and not detectable after 1 and 2 µM paraquat.	Stajner, et al., 2003/4
8	*Triticum aestivum* L.	Paraquat	Herbicide	0-60 µM	Foliar	Increased MDA content, SOD, APX and POD activities.	Ekmekci and Terzioglo, 2005
9.	*Catharanthus roseus* L.	Triadimefon	Fungicide	0-15 mg l^{-1}	Soil drenching	H_2O_2 and electrolyte leakage were reduced. LPO and proline oxidase activities decreased whereas γ –glutamyl kinase (γ-GK) increased.	Jaleel, et al., 2007a
10	*Triticum aestivum* L.	2, 4- DCP (2,4-dichlorophenols) and PCP (pentachlorophenols).	Herbicide	0-5 mg kg^{-1}	Soil treatment	TBARS, free phenols content and guaiacol POD activity increased whereas inhibition in SOD and CAT activity.	Michalowicz, et al., 2009
11.	*Daucus carota* L.	Hexaconazole and paclobutrazol	Fungicide	0-20 mg L^{-1}	Soil drenching	Increased in α and β-amylases, starch hydrolyzing, GSH and APX enzymes activities.	Gopi, et al., 2007
12	*Momordica charantia* L.	Dimethoate	Organophosphorous insecticide.	0-200 ppm	Seedlings	Increased lipid peroxidation, electrolyte leakage and activities of SOD, CAT and POD.	Mishra, et al., 2009
13	*Triticum aestivum* L.	Prometryne	herbicides	0–24 mg kg^{-1}	soil	Antioxidant activities like SOD, POD, CAT,APX and GST showed a general increase at low prometryne concentrations but a decrease at high levels.	Jiang and Yang, 2009
14	*Nicotiana tabacum*	Carbendazim	Fungicide	0-2.6 mM	Foliar spray	It doesnot increase SOD, GPX, CAT and APX activities or H_2O_2 foliar accumulation.	Garcia, et al., 2001
15	*Cucumis sativa*	Paraquat	herbicide		Exogenous treatment /pretreated	Increased the activities of antioxidants such as SOD, CAT, GPX, APX, DHAR, MDHAR, GR, GSH and reduced ascorbate (AsA)	Jing, et al., 2009
16	*Triticum aestivum* L.	Prometryn	Herbicide	0-24 mg kg^{-1}	Soil	Accumulation of TBARS. Activities of enzymes like SOD, POD, CAT, APX and	Lei and Hong, 2009

						GST showed a general increase at low concentration but a decrease at high levels.	
17	*Raphanus sativus* L.	Triadimefon and Hexaconazole.	Fungicide	Triadimefon @ 10 mg L^{-1} and hexaconazole @5 mg L^{-1}	Seedling	Membrane integrity like electrolyte leakage and lipid peroxidation and riboflavin content were estimated which increased after triazole treatment while it decrease the membrane leakage of the tuber .	Sridharan, et al., 2009
18	*Triticum aestivum* L	Isoproturon	Herbicide	0-20 mg/kg	Soil	Increased TBARS content. Activities of the antioxidant enzymes like SOD and POD showed increase at low concentration and a decrease at high concentration whereas CAT activity showed progressive suppression under the isoproturon treatment.	Yin, et al., 2008
19	*Vigna radiata* .L.	Glyphosate	herbicide	0-10mM	Seedlings root	Inhibit 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), obstructing synthesis of tryptophan, phenylalanine, tyrosine and other secondary products.elevated exptression of antioxidative enzymes i.e. CAT, POD, GST after glyphosate treatment.	Basantani, et al., 2011
20	*Cucurbita maxima* L.	Paraquat	Herbicide	50-1000 µM	Foliar Spray 4-leaf plant	SOD expression was not responsive to oxidative stress. Both the chloplastic APX activity and AsA content in the older leaves were reduced by paraquatthan younger leaves. Cellular leakage and lipid peroxidation were lowered.	Yoon, et al., 2011

Table 5. Effects of pesticides exposure on yield attributes of different plant species.

S No	Plant species	Pesticide used	Class	Dosage	Mode of application	Effect	References
1	*Vigna radiata* L.	Chlorpyrifos	Organophosphate	0-1.5 mM	Foliar	Yield attributing characters like number of pods plant^{-1}, number of seeds pod^{-1} and weight of 100 seeds increased at 0.3 mM insecticidal treatment whereas increase in insecticide level had a negative impact on above said parameters.	Parween, et al., 2011a
2	*Abelmoschus esculentus* L.	Chitosan		0-125 ppm	Foliar application at 25, 40 and 55 day	Number of fruits/plant, fruit size etc.	Mondal, et al., 2012.
3	*Vigna radiata* L.	Methamidophos	Insecticide	0-1250 mL ha^{-1}	foliar	Increased in grain pod^{-1}, seed weight, seed yield, @ 1000mL ha^{-1}	Khan, et al., 2006
4.	*Cicer arietinum* L.	Lorsban,Decis, Pyrifos,Karate, Ripcord	insecticides	875 ml acre^{-1}, 200 mlacre^{-1}, 1125 ml acre^{-1}, 250 ml acre^{-1}, 225 ml acre^{-1}.	Sprayed at 45 days after planting and at pod initiation stage	Grain yield was significantly higher after pryrifos treatment as compared to other insecticide tested	Khan, et al., 2009; Mahmood and Shah, (2003)
5.	*Lens culinaris* L.	Mancozeb	Insecticide	0-0.5%	Seed treatment	Root length, shoot length, biomass, number of leaves, flowers, pods and leaf area increased @ 0.1% and thereafter decreased	Bashir, et al., 2007b
6.	*Triticum aestivum* L.	Imidacloprid, tebuconazole	Insecticide, fungicide,	0.7 and 1.05g a.i.	Seed treatment	Increase in total grain yield of the wheat crop.	Ahmed, et al., 2001
7	*Daucus carota* L.	Hexaconazole and paclobutrazol	Fungicide	0-20 mg L^{-1}	Soil drenching	Fresh and dry weight of leaves and tuber increased under hexaconazole treatment.	Gopi, et al., 2007
8	*Vigna unguiculata* L.	Dimethoate	Organophosphoros insecticide	0-200 ppm	Seedling	Significant decrease under higher concentration in leaf area, shoot and root length, fresh and dry mass of shoot, root and leaf whereas at lower concentration all the above said parameters	Mishra, et al., 2008

						enhanced significantly except root parameter.	

Table 6. Effects of pesticides exposure on residues of different plant species.

S No.	Plant species	Pesticide Detected	Class	Range of detected residues (ppm)	References
1.	*Malus domestica* L.	Dieldrin Disulfoton Endosulfan sulfate Parathion Chlorpyrifos	Insecticides	05-196 98-298 43-110 256-681 278-530	Latif, et al., 2011.
2	*Citrus* × *sinensis* L.	Dieldrin Disulfuron Endosulfan sulfate Parathion Triadimefon Chlorpyrifos	Insecticide and fungicides.	90-187 08-280 2.8-10 340-149 14-710 280-570	Latif, et al., 2011
3	*Vitis vinifera* L.	Disulfoton Endosulfan sulfate Parathion Chlorpyrifos.	Insecticides	45-280 0.9 59-150 60-680	Latif, et al., 2011
4.	Anise, Basil, Caraway, Chamomile, Marjoram, Dill, Mint,	Malathion, Sulfur, Chlorpyrifos, Profenofos, Diazinon, Chlorpyrifos-methyl, Cypermethrin.	Fungicides, insecticides,	0.010 - 8.563	Farag, et al., 2011
5	*Tallinum triangulare, Chochorus olitorius, Amaranthus caudatus, Celocia argentea, Capsicum frutescens, Lycopersicon esculentum, Rhapinus sativus, Zea mays, Dioscorea alata, Musa paradiscicica, Carica papaya.*	Paraquat	Herbicide	0.04-0.27 ppm.	Akinloye, et al., 2011
7	*Solanum melongena* L.	Cartap	Insecticide	0.954- 3.300 mg/kg.	Alam, et al., 2011.
8	*Abelmoschus esculentus* (L.) Moench	Cypermethrin	Insecticide	0.001 ppm	Shinde, et al., 2012.

 ACCEPTED MANUSCRIPT