APPLICATION OF BIOFERTILIZERS

Contents

Biofertilizers can be inoculated on seeds as well as in the roots of different crop plants under ideal conditions. They can also be applied directly to the soil. There are certain approaches to the application of biofertilizers as described below:

METHODS OF APPLICATION

Seed inoculation OR seed treatment

This is the most common practice of applying biofertilizers. In this method, the biofertilizers are mixed with 10% solution of jaggary. The slurry is then poured over the seeds spread on a cemented floor and mixed properly in a way that a thin layer is formed around the seeds. The treated seeds should be dried in the shade overnight and then they should be used. Generally, 750 grams of biofertilizer is required to treat the legume seeds for a one-hectare area.

Seedling root dip

The seedling roots of transplanted crops are treated for half an hour in a solution of biofertilizers before transplantation in the field. In this method, the seedlings required for one acre are inoculated using 2–2.5 kg biofertilizers. For this, a bucket having adequate quantity of water is taken and the biofertilizer is mixed properly. The roots of the seedlings are then dipped in this mixture so as to enable the roots to get inoculum. These seedlings are then transplanted. This method has been found very much suitable for crops like tomato, rice, onion, cole crops and flowers.

Main field application

This method is mostly used for fruit crops, sugarcane and other crops where localized application is needed. At the time of planting of fruit trees, 20 g of biofertilizer mixed with compost is to be added in the ring of one sapling. The same quantity of biofertilizer may be added in the ring soil of the seedling after it has attained maturity. Sometimes, biofertilizers are also introduced in the soil but this may require four to ten times more biofertilizers. Before use, the inoculants should be incubated with the desired amount of well decomposed granulated farmyard manure (FYM) for 24 hours. The FYM acts as nutrition medium and adjuvant (carrier) for biofertilizers.

Self-inoculation or tuber inoculation

This method is exclusively suitable for application of *Azotobacter*. In this method, 50 liters of water is taken in a drum and 4–5 kg of *Azotobacter* biofertilizer is added and mixed properly. Planting materials required for one acre of land are dipped in this mixture. Similarly, if we are treating potato, then the tubers are dipped in the mixture and planting is done after drying the materials in the shade.

LIQUID BIOFERTLIZER APPLICATION

Seed Treatment

Seed treatment is the most common method adopted for all types of inoculants. The seed treatment is effective and economic. For small quantities of seeds (up to 5 kg), the coating can done in a plastic bag. For this purpose, a plastic bag sized 21” x 10” or larger can be used. The bag should be filled with 2 kg or more of seeds. The bag should be closed in such a way so as to trap the air as much as possible. The bag should be squeezed for 2 minutes or more until all the seeds are uniformly wetted. Then the bag is opened, inflated again and shaken gently. The shaking can stop after each seed gets a uniform layer of culture coating. The bag is opened and the seeds are dried in the shade for 20–30 minutes. For large amounts of seeds, the coating can be done in a bucket and the inoculant can be mixed directly by hand. Seed treatment with *Rhizobium*, *Azotobacter*, *Azospirillum*, along with PSM can be done.

The seed treatment can be done with any of two or more bacteria. There is no side (antagonistic) effect. The important things that have to be kept in mind are that the seeds must be first coated with *Rhizobium*, *Azotobacter* or *Azospirillum*. When each seed gets a layer of these bacteria, then the PSM inoculant has to be coated as an outer layer. This method will provide a maximum number of all bacteria required for better results. Treatments of seeds with any two bacteria will not provide a maximum number of bacteria on individual seeds.

Root dipping

This method is used for application of *Azospirillum*/ /PSM on paddy transplanting/ vegetable crops. The required quantity of *Azospirillum/* /PSM has to be mixed with 5–10 liters of water at one corner of the field and the roots of seedlings have to be dipped for a minimum of half-an-hour before transplantation.

Soil application

Use 200ml of PSM per acre. Mix PSM with 400 to 600 kgs of cow dung FYM along with ½ bag of rock phosphate if available. The mixture of PSM, cow dung and rock phosphate has to be kept under any tree or in the shade overnight and 50% moisture should be maintained. The mixture is used for soil application in rows or during leveling of soil.

Some recommended liquid biofertilizers and their method of application and quantity to be used for different crops are as follows:

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Crop	Recommended Biofertilizer	Application method	Quantity to be used
Field crops **Pulses** **Chickpea, pea, groundnut, soybean, beans, lentil, alfalfa, berseem clover, green gram, black gram, cowpea and pigeon pea**	*Rhizobium*	Seed treatment	200 ml/acre
Cereals **Wheat, oat, barley**	*Azotobacter/ Azospirillum*	Seed treatment	200 ml/acre
Rice	*Azospirillum*	Seed treatment	200 ml/acre
Oil seeds, mustard, sesame, linseeds, sunflower, castor	*Azotobacter*	Seed treatment	200 ml/acre
Millets **Pearl millet, finger millet, kodo millet**	*Azotobacter*	Seed treatment	200 ml/acre
Maize and sorghum	*Azospirillum*	Seed treatment	200 ml/acre
Forage crops and grasses **Bermuda grass, Sudan grass, Napier grass , paragrass, star grass etc.**	*Azotobacter*	Seed treatment	200 ml/acre
Other misc. plantation crops **Tobacco**	*Azotobacter*	Seedling treatment	500 ml/acre
Tea, coffee	*Azotobacter*	Soil treatment	400 ml/acre
Rubber, coconuts	*Azotobacter*	Soil treatment	2–3 ml/plant
Agro-forestry/fruit plants **All fruit/agro-forestry (herbs, shrubs, annuals and perennials) plants for fuel wood, fodder, fruits, gum, spice, leaves, flowers, nuts and seeds**	*Azotobacter*	Soil treatment	2–3 ml/plant at nursery
Leguminous plants/ trees	*Rhizobium*	Soil treatment	1–2 ml/plant

Note: Doses recommended when count of inoculum is 1×10^8 cells/ml; then doses will be ten times more. Besides the above-said nitrogen fixers, phosphate solubilizers and potash mobilizers at a rate of 200 ml/acre could be applied for all crops.

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APPLICATION OF DIFFERENT TYPES OF BIOFERTILIZERS

Nitrogen biofertilizer application:

- *Rhizobium* for legume crops.
- *Azotobacter* and *Azospirillum* for non-legume crops.
- *Acetobacter* for sugarcane only.
- Blue-green algae (BGA) and *Azolla* for low-land paddy.
- *Frankia* for *Casuarina* and *Alnus*.

Rhizobium

Table 1. *Rhizobium* spp. suitable for different crops

Rhizobium sp.	Crops
R. leguminosarum	Pea (*Pisum*), *Lathyrus*, *Vicia*, lentil (*Lens*)
R. trifoli	Berseem clover (*Trifolium*)
R. phaseoli	Kidney bean (*Phaseolus*)
R. lupine	*Lupinus*, *Ornithopus*
R. japonicum	Soybean (*Glycine*)
R. meliloti	*Melilotus*, alfalfa (*Medicago*), fenugreek (*Trigonella*)
***Rhizobium* spp.**	Cowpea, clusterbean, greengram, blackgram, redgram, groundnut, mothbean, dhaincha, sunn hemp, *Glyricidia*, *Acacia* etc.

Methods of application of Rhizobium inoculants:

Seed treatment has been found to be the suitable method of *Rhizobium* inoculation. Some adhesive is used to make proper contact between seeds and inoculants (bacteria). About 900 g soil base culture is sufficient to inoculate the seeds for an area of one hectare in case of legumes. A 10% jaggery (gur) solution is used as sticker for *Rhizobium* cells to seed. First, the solution is spread over the seeds and mixed to build up a thin coat over the seeds. After ascertaining the proper coating of slurry over the seeds, the inoculant is sprinkled over the seeds and the content is again mixed thoroughly. Then the content is dried in the shade by spreading thinly on a polythene sheet for at least overnight.

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Azotobacter

Field experiments carried out on *Azotobacter* indicated that this is suitable when inoculated with seeds or seedlings of crop plants like onion, aubergine, tomato and cabbage under different agro-climatic conditions. *Azotobacter* inoculation curtails the requirement for nitrogenous fertilizers by 10 to 20% under normal field conditions.

Azospirillum

Azospirillum inoculation helps to improve the vegetative growth of the plants, cutting back on nitrogenous fertilizers by 25–30%. So far, only four species of *Azospirillum* have been identified. They are *A. lipoferum*, *A. brasilense*, *A. amazonense* and *A. iraquense*. In Indian soils, *A. brasilense* and *A. oferum* are very common.

Acetobacter

Under field conditions, the yield of sugarcane increases after *Acetobacter* inoculation. Productions of auxins and antibiotic type substances have also been observed after its application.

Blue-green algae

The blue-green algae inoculum is applied after transplantation of rice crops in the main field. The inoculum required is 10 kg/ha. For higher nitrogen fixation, 3 to 4 t/ha of farmyard manure and 200 kg/ha of superphosphate are applied.

Azolla

Azolla is applied to the main field as a green manure crop and as a dual crop. As a green manure crop, *Azolla* is allowed to grow on the flooded fields for 2 to 3 weeks before transplanting. Later, water is drained and *Azolla* is incorporated by ploughing in. As a dual crop, 1000 to 5000 kg/ha of *Azolla* is applied to the soil one week after transplanting. When a thick mat forms, it is incorporated by trampling. The leftover *Azolla* develops again and is trampled in as a second crop. For better growth of *Azolla*, 25 to 50 kg/ha of superphosphate is applied and standing water of 5 to 10 cm is maintained continuously in the rice fields.

Frankia

Frankia inoculation enhances the growth, nodulation, nitrogenase activity of nodules and nodule dry weight of *Casuarina* and *Alnus* plants.

Phosphorus biofertilizer application

Phosphobacteria are a type of biofertilizer. Phosphorus is a major nutrient for plants, inducing vigorous growth and also contributing to plant disease resistance. Phosphorus helps in root formation and plant growth. The plants utilize only 10–15% of the applied phosphate. The balance 85–90% remains in insoluble form in the soil. The bio-promoters have highly efficient phosphate-solubilizing bacteria (*Bacillus megaterium*) that grow and secrete organic acids, which dissolve this unavailable phosphate into soluble form and make it available to the plants. Thus, the residual phosphate fertilizers in the soil can be well utilized and the external application can be optimized.

The broth is prepared in flasks and inoculum from a mother culture is transferred to flasks. The culture is grown under shaking conditions at 30±2°C as submerged culture. The culture is incubated until maximum cell population of 1010 to 1011 cfu/ml is produced. Under optimum conditions, this population level could be attained within 4 to 5 days for *Rhizobium*; 5 to 7 days for *Azospirillum*; 2 to 3 days for phosphobacteria and 6–7 days for *Azotobacter*. The culture obtained in the flask is called starter culture. For large-scale production of inoculant, inoculum from starter culture is transferred to large flasks/seed tank fermenter and is grown until the required cell count is reached.

The recommended dosage of *Azospirillum* is adopted for phosphobacteria inoculation; for combined inoculation, both biofertilizers as per recommendations are to be mixed uniformly before use.

Inoculum preparation for phosphorus biofertilizer

Prepare appropriate medium specific to the bacterial inoculant in 250 ml, 500 ml, 3 liter and 5 liter conical flasks and sterilize. The media in 250 ml flasks are inoculated with an efficient bacterial strain under aseptic conditions. Keep the flasks at room temperature in a rotary shaker incubator (200 rpm) for 5–7 days. Observe the flasks for growth of the culture and estimate the population, which serves as the starter culture. Using the starter culture (at log phase) inoculate the larger flasks (500 ml, 3 liter and 5 liter) containing medium, after obtaining growth in each flask. The above medium is prepared in large quantities in a fermenter, sterilized well, cooled and kept ready.

The medium in the fermenter is inoculated with the log-phase culture grown in the 5-liter flask. Usually 1–2% inoculum is sufficient; however, inoculation is done up to 5%, depending on the growth of the culture in the larger flasks. The cells are grown in the fermenter by providing aeration (passing sterile air through a compressor and sterilizing agents like glass wool, cotton wool, acid etc.) and giving continuous stirring. The broth is checked for the population of the inoculated microorganism and contamination, if any, during the growth period. The cells are harvested with a population load of 10^9 cells ml^{-1} after the incubation period. There should not be any fungal or any other bacterial contamination at a 10^{-6} dilution level. It is not advisable to store the broth after fermentation for periods longer than 24 hours. Even at 4°C, the number of viable cells begin to decrease.

PSB can be used for all crops, including paddy, millets, oilseeds, pulses and vegetables.

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The methods recommended for application are:

1. Seed treatment;

2. Seedling dipping;

3. Soil application.

In addition to these, combined use of bacterial biofertilizers can also be done. Bacterial inoculants should not be mixed with insecticide, fungicide, herbicide and fertilizers. Seed treatment with bacterial inoculant is to be done at last when seeds are treated with fungicides.

Compost application

The quality of compost depends principally on the feedstock and the right composting process. Compost is used in two ways in agricultural practice. One is to improve cultivated soil and the other is to manufacture substrates for growth of horticultural and floricultural plants. Adding mature compost in the soil has positive effects due to the increase in soil organic matter, which means an improvement of some physical and chemical characteristics such as porosity, air/water ratio, cation exchange capacity (CEC), pH, available amount of nutrient elements, etc.

Application of compost in gardens

Compost is used in the following cases:

1. As a soil enrichment material in ornamental plant nurseries and plant exteriors of hotels, instead of peat;
2. In filling new gardens, when mixed with the soil in a 1:3 ratio (compost: soil);
3. In new grass plants instead of turf, but must be free from weed seeds, otherwise they may cause problems;
4. In old degraded lawns due to intensive use by customers, the so-called "cap" applies, i.e. surface-spread sifted compost and then re-sown.

The compost is applied in the gardens of the hotels especially before the start of season, when new gardens are renewed or built. The quantities used annually in the gardens depend on the scope of work renovations performed.

Benefits from the use of compost are:

1. The soil is enriched with organic matter.

2. The structure and properties of soil are improved as considered of importance.

3. The nutrients are recycled from the plants by pruning back through the compost.

4. It is cheaper material than the humus trade.

However, there are some drawbacks:

1. The presence of weed seeds can carry weeds to clean regions and infect them.

2. The non-standardization of the compost in small sacks limits its use.

3. Lack of screening for the presence of large pieces of the raw materials used. So there are increased costs due to higher number of workers for their removal.

Nano-fertilizer inoculation

A few studies have suggested that nanoparticles delivered at a safe dose may help in promoting plant growth and overall yield. Multi-walled carbon nanotubes (MWCNTs) have been reported to have the ability to increase the seed germination and growth of tomato and to enhance the growth in tobacco cells and mustard plants.

On the basis of germination index and relative root elongation, oxidized MWCNTs have been shown to be more effective at lower concentrations than non-oxidized MWCNTs. Moreover, nano-silver performs better than silver nitrate in improving the seed yield and preventing leaf abscission in borage plants. The plant hormone ethylene plays a key role in leaf abscission, and silver ions have been shown to inhibit ethylene by replacing copper ions from the receptors.

Employing the foliar spray method, both nano-silver and silver nitrate were sprayed on different sets of plants, and it was observed that nano-silver was effective at a lower concentration than silver nitrate. The effect of biosynthesized silver nanoparticles on emergence of seedlings and various plant growth parameters of many economically important plant species were studied by Namasivayam and Chitrakala (2011). Mahajan et al. (2011) used the agar plate method to test the effect of nano-ZnO particles on the growth of *Vigna radiata* and *Cicer arietinum*. Evidence of nanoparticles adsorbed on the root surface was provided using correlative light and scanning electron microscopy. Inductively coupled plasma/atomic emission spectroscopy (ICP-AES) studies revealed the absorption of ZnO nanoparticles by seedlings. Using the foliar spray method, Burman et al. (2013) studied the effect of ZnO nanoparticles on the growth and antioxidant system of chickpea seedlings. They found that lower concentration (1.5 ppm) of ZnO nanoparticles has a positive effect on chickpea seedling growth.

Moreover, seedlings treated with ZnO nanoparticles showed improved biomass accumulation, which may be due to lower reactive oxygen species (ROS) levels as evident from lower malondialdehyde (MDA) content. Similarly, Prasad et al. (2012) observed that treatment with nano-zinc at lower concentration (1,000 ppm) had positive effects on plants, but caused toxicity symptoms at higher concentration (2,000 ppm) pointing out the importance of their meticulous use. Furthermore, during field experiments, they reported usage of a 15 times lower dose of ZnO nanoparticles compared to the recommended dose of $ZnSO_4$ and recorded 29.5% higher pod yield.

Likewise, ZnO nanoparticles showed root elongation in *Glycine max* at a concentration of 500 ppm but reduction in size at higher concentrations of ZnO. A study aimed to investigate the effects of ZnO and CeO_2 nanoparticles (400 ppm) on *Cucumis sativus* fruit quality showed that both these nanoparticles resulted in increased starch content and could alter the carbohydrate pattern.

Lu et al. (2002) showed the productive effect of a mixture of SiO_2 and TiO_2 nanoparticles in *G. max* with an increase in water and fertilizer uptake capacity and stimulation of nitrate reductase and antioxidant activity. Studies demonstrating the effect of nano-TiO_2 in promoting photosynthesis and growth in spinach have also been conducted, in which enhancement of the photosynthetic processes under both visible and ultraviolet light has been reported due to the pivotal role of TiO_2 (Leiet al. 2007). Zheng et al. (2005) reported that TiO_2 nanoparticles have 73% higher dry weight, threefold higher photosynthetic rate and a 45% increase in the chlorophyll *a* content after seed treatment in spinach.

As suggested, the enhanced photosynthetic rate may be due to the increase in the absorption of inorganic nutrients which enhance the utilization of organic substances and the quenching of oxygen free radicals. Unlike most of the studies showing negative impact of nanoparticles at higher concentrations, Mahmoodzadeh et al. (2013) reported that up to 2,000 ppm of TiO_2 nanoparticles leads to increased seed germination and seedling vigour in *Brassica napus*. Shah and Belozerova (2009) studied the effect of different metal nanoparticles, such as silicon (Si), palladium (Pd), gold (Au) and copper (Cu), on lettuce seed germination. They reported that nanoparticles showed positive influence at different concentration ranges: Pd and Au at lower concentrations, Si and Cu at higher concentrations and Au and Cu in combined mixture. Likewise, in a field study, Quoc Buu et al. (2014) reported an increased seed germination rate in *G. max* as compared to control when treated with nanocrystalline powder of iron, cobalt and copper at an extra-low concentration. In addition, a marked increase was observed in the chlorophyll index, number of nodules and crop yield. Arora et al. (2012) reported that foliar spray of gold on *Brassica juncea* plants in field experiments showed a positive effect, as it resulted in increased plant height, stem diameter, number of branches, number of pods and seed yield.

Interestingly, gold nanoparticles also improved the redox status of treated plants. Suriyaprabhaet al. (2012) reported that treatment with SiO_2 nanoparticles in maize plants significantly enhanced the plant dry weight and also enhanced the levels of organic compounds such as proteins, chlorophyll and phenols.

Genetically engineered microbes application

There are many biotechnological applications of genetically engineered microorganisms that potentially may fall under the purview of the Toxic Substances Control Act (TSCA), including a number of uses that are relevant to agriculture. These include intergeneric microorganisms used as biofertilizers such as symbiotic nitrogen-fixers, e.g. *Sinorhizobium meliloti* and *Bradyrhizobium japonicum*. Field tests of numerous intergeneric rhizobia have gone through review under TSCA, and one particular strain of *S. meliloti*, RMBPC-2, was approved in 1997 for limited commercialization.

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In the future, there could be more submissions for more rhizobia for increased nitrogen-fixation ability, or perhaps, for enhanced nodulation efficiency. In addition, applications for other symbiotic nitrogen fixers, such as the actinomycete *Frankia*, which is a Gram positive bacterium that forms symbiotic relationships with certain plants such as woody angiosperms referred to as actinorhizal plants, are a possibility. There may also be submissions for free-living nitrogen-fixing microorganisms. In addition to nitrogen-fixing intergeneric microorganisms, other biofertilizer applications that would be reviewed under TSCA include phosphate-solubilizing microorganisms, mycorrhizal fungi or other endophytic microorganisms that aid in nutrient absorption, plant hormone production, or act by other mechanisms that may increase plant productivity.

TIPS TO GET GOOD RESPONSE TO BIOFERTILIZER APPLICATION

- Biofertilizer products must contain an appropriate population of good effective strains and should be free from contaminating microorganisms.
- Select the right combination of biofertilizers and use before the expiry date.
- Use the suggested method of application and apply at appropriate time as per the information provided on the label.
- For seed treatment, adequate adhesive should be used for better results.
- For problematic soils, use corrective methods like lime or gypsum pelleting of seeds or correction of soil pH by use of lime.
- Ensure supply of phosphorus and other nutrients.

PRECAUTIONS BEFORE BIOFERTILIZER APPLICATION

- Biofertilizer packets need to be stored in a cool and dry place away from direct sunlight and heat.
- Right combinations of biofertilizers have to be used.
- As *Rhizobium* is crop specific, one should use it for the specified crop only.
- Other chemicals should not be mixed with the biofertilizers.
- When purchasing, one should ensure that each packet is provided with all necessary information like name of the product, name of the crop for which it is intended, name and address of the manufacturer, date of manufacture, date of expiry, batch number and instructions for use.

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- The packet has to be used before its expiry, only for the specified crop and by the recommended method of application.
- Biofertilizers are live products and require care in their storage.
- Both nitrogenous and phosphate biofertilizers are to be used to get the best results.
- It is important to use biofertilizers along with chemical fertilizers and organic manures. Biofertilizers are not a replacement of fertilizers but can supplement plant nutrient requirements.

ENVIRONMENTAL LIMITATIONS FOR APPLICATION OF BIOFERTILIZERS

- Unavailability of suitable carrier resource constraint
- Market level constraints and lack of awareness of farmers
- Lack of quality assurance and limited resource generation for biofertilizers production
- Seasonal and unsure requirement
- Soil and climatic factors and inadequately experienced staff
- Native microbial population, faulty inoculation techniques and mutation during fermentation

IMPACTS ON HUMAN HEALTH

While fertilizers cause relatively little harm to wildlife at least in comparison to the damage caused by pesticides, they are hazardous, in certain circumstances, to human health. These include:

- High nitrate concentrations in drinking water, which can result in clinical methaemoglobinaemia (often referred to as the blue baby syndrome);
- Dust exposure, which is the main occupational health problem in fertilizer manufacture;
- Ingesting of nitrate, which is implicated in a number of serious diseases, like gastric, bladder, esophageal cancer.

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Occupational health and safety (OHS) needs to be properly managed. A farmer's OHS system helps ensure effective control of OHS risks, prevent work-related illness or injury and achieve compliance with regulations and standards.

Particularly appropriate for the new economic and occupational structure of farmer work, practitioners, researchers and other stakeholders are interested in assessing and managing the existing OHS risks. The goals concern:

1) The identification of effective practices in OHS risk management, and

2) Using a simple framework of good practice.

Products (or material) safety data sheets (MSDS) (appendix) serve two purposes, as they inform those concerned in handling chemicals of the hazards involved and they also provide the basis for risk assessments. Safety data sheets should be provided at all stages in the distribution chain and some countries have required their use under legislation.

In addition to the normal production properties, MSDS are required to provide health hazard and eco-toxicological information, which is generally difficult to obtain and interpret.

Hazards for Farmers

Farmers using biofertilizers may be exposed to many hazards:

HEAT

Heat-related illness can be deadly. Every year, thousands of workers become sick from exposure to heat, and some even die. These illnesses and deaths are preventable.

Workers exposed to hot and humid conditions are at a high risk of heat illness, especially if they are doing heavy work tasks or using bulky protective clothing and equipment. New workers may also be at greater risk than others if they have not built up tolerance to hot conditions. Employers must take steps to help workers become acclimated.

Heat-related illnesses, while potentially deadly, are easily preventable. When working in hot conditions, remember "WATER, REST and SHADE." Drink water every 15 minutes, even when not thirsty. Wear a hat and light-coloured clothing. Rest in the shade. Be sure to watch out for fellow workers and know your location in case you need to call for assistance. Get help right away if there are any signs of illness.

MUSCULOSKELETAL INJURIES

Workers in agricultural operations for crop productions typically use repetitive motions in awkward positions, which can cause musculoskeletal injuries.

Ergonomic risk factors are found in jobs requiring repetitive, forceful or prolonged exertions of the hands; frequent or heavy lifting, pushing, pulling or carrying of heavy objects; and prolonged awkward postures. Vibration and cold may intensify these conditions.

Ergonomic protections. Some methods for reducing musculoskeletal injuries include proper tools, padding to reduce vibration and fewer activities with high repetition.

LADDERS & FALLS

Deaths and injuries from falls remain a major hazard for farm workers.

VEHICLE HAZARDS

Injuries from vehicle accidents are serious and debilitating to farm activities.

HAZARDOUS EQUIPMENT AND MACHINERY

Farm workers routinely use knives, hoes and other cutting tools; work on ladders; or use machinery in their shops. However, these simple tools can be hazardous and have the potential for causing severe injuries when used or maintained improperly.

1. All tools should be maintained in good condition and used according to the manufacturers' instructions.
2. Power tools must be properly grounded or double insulated and all guards or shields must be in place.
3. Farm workers should wear proper personal protective equipment (PPE) and make sure that clothing has no strings or loose ends that could be caught by machinery. Long hair should be tied back to prevent entanglement.
4. In addition, shops should be well lit and have clear walkways to eliminate slips, trips and falls.

GRAIN BINS AND SILOS

While safety issues surrounding grain bins and silos are sometimes overlooked on farms, they pose many dangers. Farm workers are exposed to suffocation or engulfment hazards when working with grain bins and silos, as well as grain dust exposures and explosions. Suffocation is a leading cause of death in grain storage bins.

Suffocation can occur when a worker becomes buried (engulfed) by grain as they walk on moving grain or attempt to clear grain built up on the inside of a bin. Moving grain acts like "quicksand" and can bury a worker in seconds. "Bridged" grain and vertical piles of stored grain can also collapse unexpectedly if a worker stands on or near it.

UNSANITARY CONDITIONS

The lack of drinking water, sanitation facilities and/or hand washing facilities can lead to many health effects. Farm workers may suffer heat stroke and heat exhaustion from insufficient intake of potable water, urinary tract infections due to urine retention from inadequate availability of toilets, agrichemical poisoning resulting from lack of hand washing facilities, and infectious and other communicable diseases from microbial and parasitic exposures.

RESPIRATORY DISTRESS

Respiratory hazards. Respiratory hazards in barns, manure pits, machinery and silos range from acute to chronic air contaminants. Farmworkers' most common respiratory hazards are bio-aerosols, such as organic dusts, microorganisms, and endotoxins and chemical toxicants from the breakdown of grain and animal waste. Inorganic dust, from silicates in harvesting and tilling, is prevalent but less significant.

Respiratory protection. Control of aerosols might include the enclosure and ventilation of tractors, applying moisture to friable material, and respirators.

NOISE

Thousands of workers every year suffer from preventable hearing loss due to high workplace noise levels, and research has shown that those who live and work on farms have had significantly higher rates of hearing loss than the general population. In fact, farming is among the occupations recognized as having the highest risks of hearing loss.

Tractors, forage harvesters, silage blowers, chain saws, skid-steer loaders, grain dryers, squealing pigs and guns are some of the most typical sources of noise on the farm. Studies suggest that lengthy exposure to these high sound levels have resulted in noise-induced hearing loss to farmworkers of all ages, including teenagers. Hearing loss is neither as dramatic nor as sudden as an injury from a tractor overturn or machine entanglement, but it is permanent.

Employers can achieve noise reduction in several ways – usually related to the maintenance of the equipment:

1. Worn, lose or unbalanced machine parts can increase decibel levels during operation. Regular lubrication and parts replacement (bearings, mufflers, silencers, etc.) reduce friction and lower noise levels.
2. Larger engines that can be operated at lower speeds reduce noise levels, and may even save fuel.
3. Vibration isolation pads may be installed under the legs of noisy equipment to reduce noise generated by the equipment vibrating on a cement floor.
4. Newer chainsaws and leaf blowers have flexible mountings to reduce vibration-induced noise as well.
5. Tractor and skid-steers can be purchased with sound-reducing cabs and tightly fitted cab doors and windows to reduce how much outside noise reaches the operator.

6. Acoustical materials may be installed on walls and ceilings to enclose sound.

In addition, employers may provide workers with personal protective equipment (PPE) but must train them in using the PPE correctly. OSHA's Safety and Health Topics Page on PPE describes proper use of personal protective equipment.

The best state of health, safety and well-being for farmers cannot be reached at once. Effective systems are based on the principle of "Plan – Do – Check - Act" (Deming, 1982). In OHS terms for companies this will require to develop a policy on what is intended to achieve, then a plan of how and when it will be done, including any necessary arrangements. Next comes the "doing" phase, when plans are implemented and then a check is made that you have done what you planned to do and that it is effective in controlling risks. Any deficiencies found need to be acted upon and rectified, so that the system performance improves continually (Smith, 2008).

According to the ISO 31000:2009 standard, risk depends both on the probability or frequency of an adverse outcome, and also on the severity of that outcome. Risk has similarly been defined generally as "the potential for realization of unwanted, negative consequences of an event" (Moraru and Băbuţ, 2010). More quantitatively (Sage and White, 1980), risk is defined as "the probability per unit time of the occurrence of a unit cost burden", and it is stated that it "represents the statistical likelihood of a randomly exposed individual being adversely affected by some hazardous event". Thus, risk has been defined at many different levels of detail. The usage of the word ‘risk’ usually has negative connotations and risks are regarded as something to be minimized or avoided.

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