Agricultural accidents and ergonomic intervention in agricultural machinery design in India

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Abstract: Accident is an unexpected event with negative consequences occurring unintentionally causes due to ignorance, lack of training and knowledge and unsuited design of implements. Ergonomics prioritizes design of safer machinery and tools for accident avoidance. To investigate about agricultural accidents surveys were conducted during the periods 2005-2007 and 2012-2014 throughout West Bengal to assess the magnitude, causes and severity of agricultural accidents through direct interviews of the victims and their related ones in case of fatal accidents with the help of developed questionnaire. Different ergonomic interventions were introduced to the agricultural workers to minimize the accidents. The total population in the periods 2005-2007 and 2012-2014 of the selected districts was recorded as 189940 including 53.6% male and 46.3% female and 297347 with 52.4% male and 47.6% female, respectively with total growth of 36.1% since 2007. Highly accident prone agricultural machinery includes thresher, power tiller, rotavator, chaff cutter, tractor etc. Accidents due to agricultural machinery, hand tools and other sources like snake bite, thunder were found to be 14.8%, 54.8% and 30.4%, respectively in 2005-2007 and 44.1%, 27.5% and 28.4%, respectively. The accident incidence rates due to hand tools was found to be decreased from 1.51 to 0.127 per 1000 hand tools due to increase of awareness about use of hand tools. But in the contrary, the accident incidence rates due to agricultural machinery was found to be increased over two mentioned periods from 1.28 to 2.62 per 1000 farm machines due to increased mechanization over the years. More awareness about the safe operation of agricultural machinery will decrease the accident incidence rate.

Keywords: agricultural accident survey, agricultural machinery, mechanization, ergonomic intervention

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1 Introduction

Accident is an unexpected event with negative consequences occurring unintentionally which may cause any time anywhere. Agricultural operations involve a unique combination of factors that cause humans, machines, and the environment to interact. Mechanization of agricultural practices has resulted in increased agricultural productivity in India but at the same time the incidence of traumatic injuries among agricultural workers seems to have increased also. Accidents are usually caused by a combination of maintenance problems, machine failures and erroneous human interventions. Many researchers have mentioned agriculture as most hazardous occupation (Verma and Chaudhari, 2016; Pawlak et al., 2017). Agricultural workers work in their fields for more than 12 hours a day in every season and weather conditions (Cież, 2010; Pawlak and Nowakowicz-Dębek, 2015). They work in

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different workplace, different level of mechanization, working tools and different daily working time along with the exposure to many hazardous mechanical factors including thermal, dust, biological and chemical ones, leads to fatigue and increases the risk of accident (Chen et al., 2022; Çalış Boyacı and Selim, 2022; Seah et al., 2021; Pawlak and Nowakowicz-Dębek et al., 2015).

The agricultural related activities caused about 5000-10000 deaths, 15000-20000 amputations and 15000 – 200000 serious injuries every year in the north India. Khadatkar et al. (2022) revealed those occupational accidents in agriculture, problems all worlds where farmers, family members and female farmers are facing risk, higher than in any other occupation. Pawlak and Nowakowicz-Dębek (2015) stated that being in a hurry, mess in the agricultural holding, misusing machines are the most common causes of accidents. Lohan et al. (2022) mentioned that during agricultural field work the tractor is often involved in accidents including combine harvesters, feed processing machines and other types of agricultural equipment which can be achieved by technical, human and organizational measures. Khadatkar et al. (2022) reviewed that the accident and injuries of operators involved in various agricultural operations account for nearly one third of all rural injuries. Kumar and Dewangan (2009) investigated agricultural accidents, their magnitude, causes, severity and economic consequences in north eastern region of India. They reported agricultural accident incident rate was 6.39 per 1000 workers/year and were non-fatal.

Farm implement related accidents accounted for 40% of the accidents, slashing of shrubs accounted for one-third of the accidents to cause cut and hit injuries of moderate severity. 25% of the accidents occurred on the way to or from the field leading to serious injuries, two-third of the accidents occurred within 4 hours of the start of work. Nag and Nag (2004) reported tractor incidents (overturning, falling from the tractor, etc.) as highest (27.7%), followed by thresher (14.6%), sprayer/duster (12.2%), sugarcane crusher (8.1%) and chaff cutter (7.8%) accidents and most of the fatal accidents resulted from the powered machinery. Gite et al. (2009) reported that 30.5% agricultural accidents were due to farm machines, 34.2% were due to hand tools and 35.3% were due to other sources like snakebites, fall in well, environmental causes, etc. Highest number of accidents were due to tractors and tractor operated implements (31%) followed by animal drawn equipment (22%), threshers (14%), electric motor/pump set (12%), chaff cutters (9%), power tillers (6%) and sprayers (4%). Of these farm machinery accidents, 5.6% accidents were fatal in nature whereas the remaining 94.4% were non-fatal.

One of the major equipment on which majority of accidents occurs is thresher. Lohan et al. (2022) and Mufti et al. (1989) reported association of 16% accidents with threshers and identified the causes as belt entanglement, electric shock and feeding crop without safety. Khadatkar et al. (2022) and Kumar et al. (2002) reported that 80%, 15% and 5% of total accidents were involved with right hand, left hand and other body parts, respectively. They have identified threshing cylinder and feeding chute as the main causes of accidents. The present implement manufacturers are making the hand tools without considering the anthropometric dimensions of the farmers which in turn affect the comfort and safety severely, as per an estimate by WHO Collaborating Centre for Research and Training in Safety, IIT Delhi. So to study about agricultural accidents in West Bengal state a survey was conducted in selected districts in the period 2005-2007 and again in 2012-2014 after introduction of some ergonomic intervention and awareness about mechanization and agricultural machinery.

2 Material and methods

2.1 Selection of districts and collection of data

The accidental survey in the West Bengal state was planned to be carried out with due consideration of the different agricultural zones of the state. The entire state was divided into four zones viz., Eastern, Western, Northern and southern zones. According to agro-climatic zones four districts were selected for the survey, viz. 24-north Pargana, Hooghly, Malda and Jalpaiguri of West Bengal state. The districts were surveyed for the period of 2005-2007 and again in 2012-2014. In each district, 40 villages were randomly selected based on the number of villages in each district, farming population of village and their accessibility.

Collection of information on the agricultural accidents was conducted by interview of the villagers by the help of questionnaire forms (questionnaire for village level information-1 and questionnaire for information from accident victim) which was found best method for data collection. The form-I provides information about agriculture land under cultivation, farming population, cropping pattern and status of mechanization. The form-II provides information about the victim, viz. name, age, address, experience of working in farm, year and month of accident, type of injury, severity, period of absence from the work and also the cost involved in treatment. A network was planned for continuous monitoring of the accident details from each selected village. Thus, accidents in agricultural field will be informed to the respective center.

2.2 Data analysis

Accident data collected through interview was analyzed and Farm implement-related and other agricultural (non-farm implement-related) accidents were separated. Time and situation of occurrence of accident were analyzed and categorized according to type of injury, cause of occurrence, machine/tools involved in accident, severity of the injury, etc. The information on the nature of injury determines its severity as per Abbreviated Injury Scale (AIS). The analysis of data provided insight into the relevant measures to be undertaken to prevent or minimize the occurrence of agricultural accidents.

3 Ergonomic interventions in agricultural machinery design

Gangopadhyay and Dev (2014) classified ergonomic interventions as engineering, administrative or behavioural. Engineering interventions are engineered or physical manipulations of hazards or routes of exposure to physical hazards. The work-related injuries and resulting disability can be prevented by using interventions potentially and also can reduce work-related musculoskeletal disorders (WMSD). Personal protective equipment is commonly used in industries for safety of the workers.

3.1 Hand tools

Kishtwaria and Rana (2012) explained about ergonomic interventions in weeding operation. For this they have introduced three weeding tools (Weeders, Kutla and small hoe) to hilly region women which were developed as per their anthropometric data and physical fitness level. The tools were made light in weight with suitable length for them, sharp inner edge for safety and suitable handle. Salunke et al. (2014) studied about interventions in manual harvesting operation and evaluated different sickles (CIAE Bhopal sickle, improved sickle I-104 and I-108) as shown in Figure 1.

Figure 1 IIT developed Cono weeder

Figure 2 Improved sickles to prevent injury

CIAE Bhopal sickle is serrated one and light in weight which prevents slippage and injury during the harvesting operation. Improved sickles are designed according to anthropometrical dimensions of agricultural workers and from the analysis I-104 was found to be the best which can be operated by all the workers with minimum fatigue and injury as compared to other sickles. A Cono Weeder (Figure 2) for Paddy fields was developed by AgFE department, IIT, Kharagpur to uproot and burry weeds in wet land. The Weeder was developed by considering anthropometric dimensions of agricultural workers to reduce the fatigue and work stress during the operation. A sugarcane stripper was developed by IISR, Lucknow and refined by OUAT, Bhubaneswar to reduce the fatigue, work stress and injury during the sugarcane stripping operation.

3.2 Hand tractor

Singh et al. (2019) designed and developed suitable vibration isolators (Figure 3) and installed at different locations of hand tractor to reduce the effect of vibration and work stress during the operation. Engine mountings were fabricated from styrene butadiene rubber (SBR) and mounted with the help of a MS flat base plate. Hand isolator was made out of two MS concentric jackets with SBR material glued in between. From the measurement and analysis, they found that engine mounting and handle isolator reduced the frequency-unweighted and frequency-weighted vibration acceleration (rms) by 50.9% and 29.8%, respectively. They have also developed vibration attenuator gloves (Figure 4) to reduce the effect of vibration in hands, arms, shoulder, etc.

Figure 3 Vibration isolator

Figure 4 Vibration attenuator gloves

Chaturvedi et al. (2012) developed interventions to reduce vibration of power tiller during operation which causes early fatigue and accident as a consequence. They have used three materials (polyurethane, rubber and combination of both the material) for the development of interventions. They found maximum vibration reduction by using rubber during all the operations.

3.3 Thresher

Dangerous Machine Regulation Act was built by Government of India in the year 1983 related to any dangerous machine used in different sector with a view to secure the operator from being injured. It includes power thresher used for threshing operation of different crops. According to this act all the moving parts like transmission system, prime mover, rollers, blowers, elevator should be secured by safeguards. Kumar et al. (2002) developed grain threshers based on ergonomic design criteria and anthropometric dimensions of the agricultural workers as shown in the Figure 6. Feeding chute dimensions were decided on the basis of dimensions of fore arm, arm length, waist height of Indian males. So, cover length was kept as 650 mm and chute length as 1000 mm. A hand warning roller was provided at the mouth of the chute which gives tactile warning to not push further. It also prevents the objects from flying to the operator which causes injury to the operator.

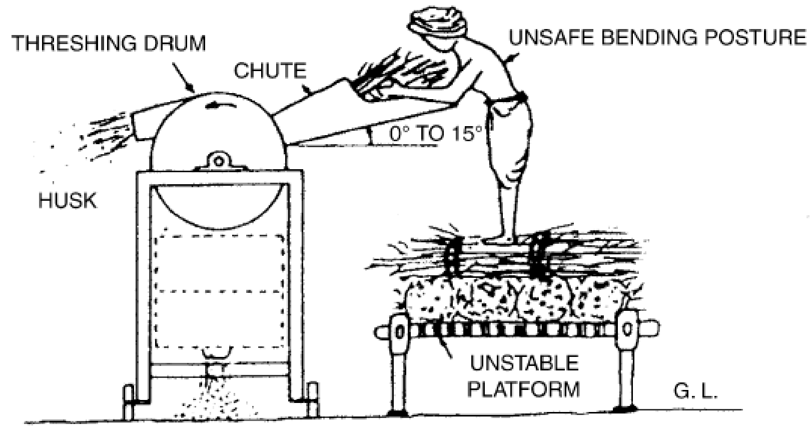

Figure 5 Existing threshing operation

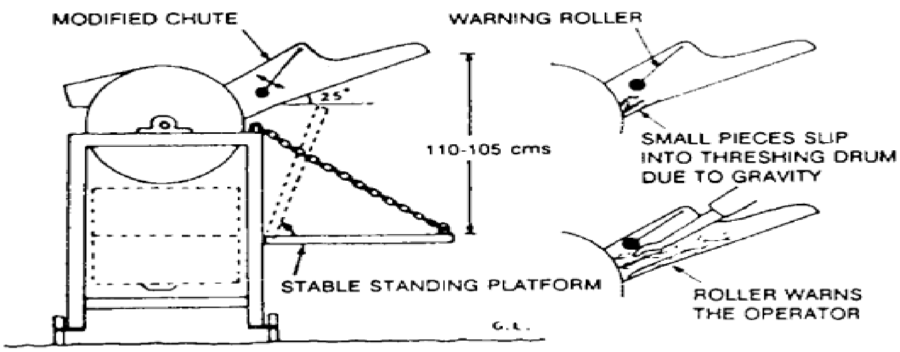

Figure 6 Safe threshing operation

Figure 7 IS: 7898-2001 manually operated chaff cutter

Figure 8 IS: 15542-2005 Power operated chaff cutter with safety guards

PAU, Ludhiana has developed safety gadgets for manual chaff cutters to minimize accidents referring to IS: 7898-2001 and for power operated chaff cutters referring to IS: 15542-2005. It includes flywheel locking device, front safety guard, gear cover, warning roller, feeding chute 900 mm long, feeding chute cover of 450 mm long and cover for flywheel and blades in case of manual chaff cutters. Similarly, in case of power operated chaff cutters flywheel locking device, front safety guard, gear cover, warning roller, feeding chute 900 mm long, feeding chute cover of 550 mm long and cover for flywheel, blades and transmission system were included. Feeding chute length was decided according to anthropometric dimension arm reach from the wall (95th percentile) to prevent the hand and fingers from accident by cylinder during feeding the crop.

3.4 Tractor

Tractor is a main source of agricultural causes which may causes due to overturning of the tractor. To prevent the accidents due to overturning Roll over protective structure is provided with tractor. A test rig was designed and developed at Agricultural and Food Engineering Department of IIT Kharagpur to evaluate various types of ROPS at different crushing strength on its axle housing. The Test Rig (TR) is used for laboratory static testing as per IS: 11821 (Part 2):1992. According to evaluation of different ROPS, a deployable ROPS for Indian tractor was designed with due consideration of anthropometric dimension of agricultural workers and design data of Indian tractors which can withstand sudden overturning and prevent accident. Since horizontal posts have number of grooves at end location, it suits a variety of tractor models.

It was tested and found that during all loading sequence it did not intrude into the operator clearance zone thereby making it acceptable for use.

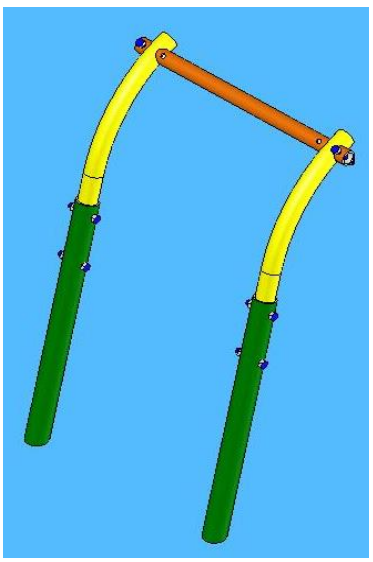

Figure 9 Deployable ROPS

A new tractor seat, IIT KGP-95, was designed and developed for Indian operator at the Agricultural and Food Engineering Department, IIT Kharagpur. The suspension spring constants of 18.9 N mm^{-1} and damping coefficient of 1.09 N-s mm^{-1} are recommended for the tractor seat. With this seat suspension, the observed vibration level at seat bottom was found to be significantly lower than the existing seats in field operations. The seat is provided with provision of adjustments for various size of the operator. The cushion material was also specially designed for better comfort. The ergonomically designed IIT KGP – 95 seat also appeared the most comfortable one for long working hours as compare to existing seats on account of the subjective perceived comfort rating (PCR) during field operations. This seat is field tested and recommended for all Indian tractors as it is suitable for large population of tractor operators.

Figure 10 Developed IIT KGP-95 seat

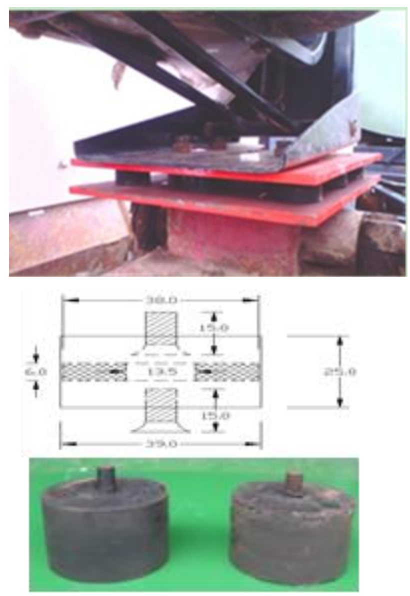

Figure 11 Seat suspension system

A new seat suspension system was designed and developed at Agricultural and Food Engineering Department, IIT Kharagpur by incorporating piezoelectric material based vibration isolator, installed beneath the tractor seat and above axle casing. This seat suspension system reduced the vibration acceleration by 36% at speed of 2.68 m s^{-1} during transportation on the tar macadam road, 28% at speed of 0.66 m s^{-1} during first tillage and 47% at speed of 0.76 m s^{-1} during second tillage for tractor of FORD make.

3.5 Manually operated machinery

A pedal operated sitting type cashew nut desheller was developed by CAET, BSKVV, Dapoli by considering ergonomic aspects. Sitting arrangement was designed according to anthropometric dimensions of agricultural workers. Feeding mechanism for cashew nut was provided to prevent accident during holding of cashew nut for deshelling. The machine was made pedal operated to minimize the fatigue during the operation. An ergonomically refined mechanical manual orange fruit harvester was developed by MPUAT, Udaipur to reduce musculoskeletal disorder and injury during harvesting. It includes telescopic pipe, cutting mechanism, camera, display, tripod and collection bag. Camera and display were provided to prevent the neck pain during harvesting.

3.6 Interventions for partially impaired persons

An intervention for soil manipulation was developed by IARI which uses body weight for soil penetration with one hand and can be lowered for tillage/soil loosening. It was provided with handle, digging fork unit and platform to apply by weight. This helps the partial impaired workers in agricultural activities. It prevents the possibility of accident due to slippage during operation of conventional digging tools with one hand.

A package of safety equipment like sprayer safety kit including goggles, apron, gloves, gum boot, etc. and SMV symbol towards minimization of agricultural accidents were introduced by AgFE department, IIT, Kharagpur to agricultural workers of West Bengal. Different training programs were organized to make the workers aware about mechanization, safety packages, safe operation of agricultural machinery, and their maintenance.

4 Results and discussion

The detailed information of the selected districts in West Bengal was collected by interview of villagers for the period 2005-2007 and again in 2012-2014 period. From the information it was found that total population of selected districts were 189940 among which 53.6% male and 46.3% female in 2005-2007. Similarly, it was found to be 297347 with 52.4% male and 47.6% female in 2012-2014 with total growth of 36.1% since 2005-2007. Total numbers of agricultural workers were found to be 151124 and 84152 in 2005-2007 and 2012-2014, respectively. Maximum no of hand tools used was found to be in Jalpaiguri district (56437) in 2005-2007 and also in 2012-2014 (109120) with a growth of 48.2%. Similarly, maximum no of agricultural machinery was found to be in Hooghly district (6114) in 2012-2014 which is 47% higher than the available machinery in 2005-2007. These data clearly shows that mechanization is increasing day by day because of the awareness about different machinery, their use and benefit.

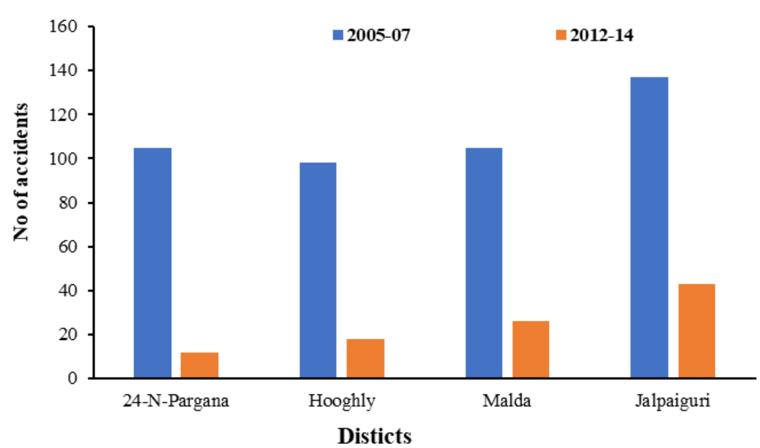

Figure 12 Number of accidents in different districts

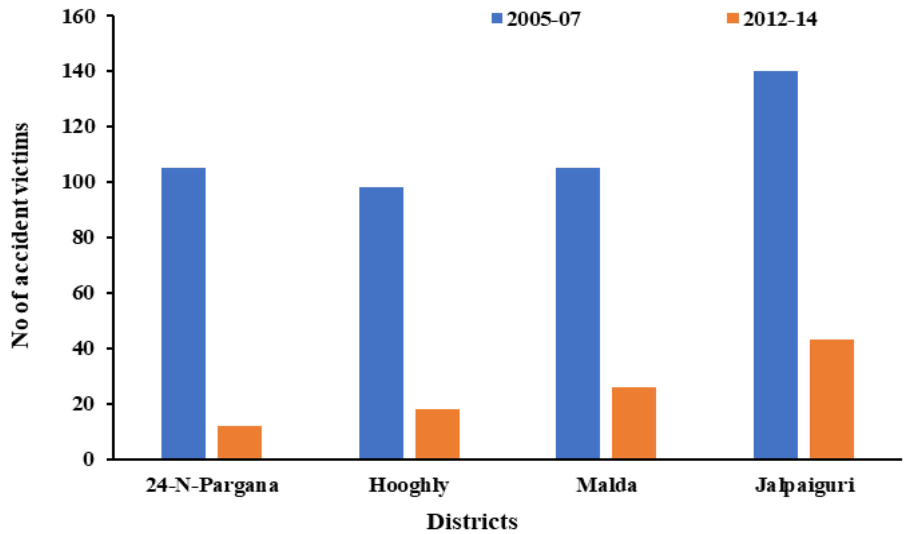

Figure 13 Number of victims of accidents in different districts

4.1 Accidents in different districts

Total no of agricultural accidents in selected districts were found to be 445 and 102 in 2005-2007 and 2012-2014, respectively in which 448 and 99 persons were found victimized. Details about the accidents in different districts are presented in Figures 12 and 13 Maximum accidents were found in Jalpaiguri district both in 2005-2007 (30.7%) and 2012-2014 (43.4%) among all districts. From Figures 12 and 13 it was observed that no of accidents was reduced in 2012-2014. This may be due to awareness about the use of improved machinery, maintenance of them, use of safety measures and ergonomic interventions developed across the country.

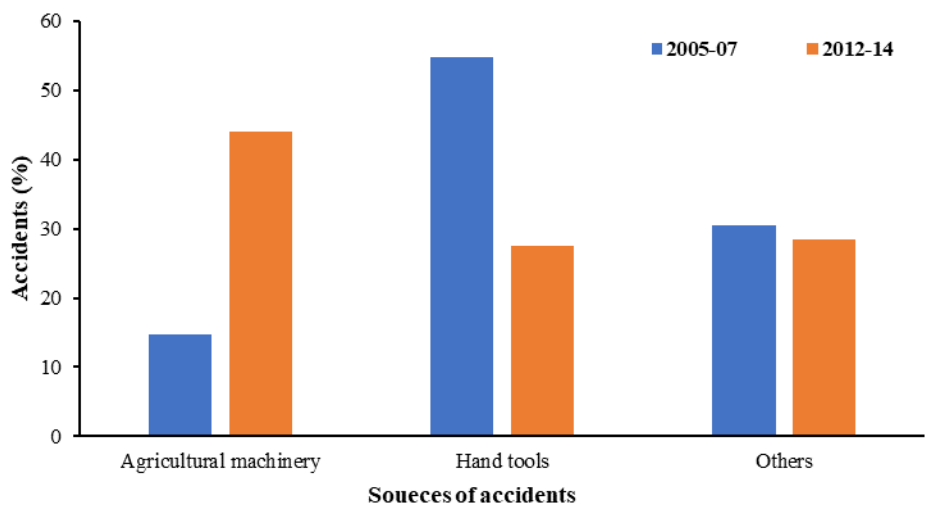

Figure 14 Source wise classification of agricultural accident

4.2 Source wise accidents

Agricultural accident occurs due to different sources like agricultural machinery, hand tools and other sources like snake bite in the field during agricultural operations, thunder during working in the field, etc. Highly accident prone agricultural machinery includes thresher, power tiller, rotavator, chaff cutter, tractor etc. From the Figure 14 it was observed that accidents due to hand tools were decreased by 17.3% since 2005-2007. This clearly shows that awareness about safe use of hand tools, use of ergonomically improved hand tools among workers is increasing day by day. But contrary to these accidents due to agricultural machinery was increased by 29.3%. Kumar and Dewangan (2009) reported 40% of total accident in north eastern region were from farm implements which was the highest among all accidents. This may be due to increase of mechanization and at the same time; lack of awareness about safe operation, lack of proper training to the agricultural workers about operation and maintenance, lack of educated workers. Accident due to all the sources was found to be maximum in Jalpaiguri district which may be due to the far location from highly mechanized districts and lack of awareness. Tables 1 and 2 shows accidents from farm machinery and hand tools in selected districts.

Table 1 Farm machinery related accidents

Districts	2005-2007		2012-2014	
	Accidents (%)	Accident Incidence rate/1000 machines	Accidents (%)	Accident Incidence rate/1000 machinery
24-N-Pargana	30.3	1.17	9.1	1.14
Hooghly	21.2	4.32	15.9	1.14
Malda	24.2	1.55	29.5	4.06
Jalpaiguri	24.3	0.77	45.4	5.08
Total		1.28		2.62

Table 2 Hand tools related accidents

Districts	2005-2007		2012-2014	
	Accidents (%)	Accident Incidence rate/1000 machines	Accidents (%)	Accident Incidence rate/1000 machinery
24-N-Pargana	20.9	0.84	18.5	0.114
Hooghly	11.1	1.13	22.3	0.13
Malda	31.2	3.71	25.9	0.47
Jalpaiguri	36.8	1.59	33.3	0.083
Total	100	1.51	100	0.127

4.5 Severity of injury

Collected data were categorized according to severity of injury on the basis of AIS. According to this categorization 23 no (5.1%) accidents were found in AIS 6 category which is fatal accidents in 2005-2007 which was found decreased in 2012-2014 that is 11 no. Nag and Nag (2004) reported 4.6%, 22%, 9.2% and 4.3% of total accidents as fatal in eastern, northern, central and southern regions, respectively. Major cause of fatal accident was found to be snake bite, thunder and tractor during both the period of survey. Gite (2005) also mentioned snake bite as major cause of fatal accident. Tiwari et al. (2002) and Singh et al. (2019) classified most of the hand tool injuries (cuts on hands, feet and shin) as minor injury. 45% of total accidents were found to be minor in the period 2005-2007 which causes due to hand tools. This was found decreased to 27% in 2012-2014 due to increase of mechanization, more use of powered machinery, awareness about safe operation of hand tools and use of improved hand tools. More awareness about the interventions, safety measures, and safe operation of agricultural accidents will decrease agricultural accidents more and more.

5 Conclusion

Agricultural mechanization was found increasing in 2012-2014 than in 2005-2007 and Agricultural accidents were found reduced in 2012-2014 as compared to 2005-2007. The accident incidence rates due to hand tools was found to be decreased from 1.51 to 0.127 per 1000 hand tools due to increase of awareness about use of hand tools. But in the contrary, the accident incidence rates due to agricultural machinery was found to be increased over two mentioned periods from 1.28 to 2.62 per 1000 farm machines due to increased mechanization over the years. It clearly shows that more and more awareness about safe use of hand tools, machinery, safety measures, developed interventions, safe operation and maintenance of agricultural machinery will decrease the incidence rate of agricultural accidents.

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