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Adoption of ergo stool for pruning and harvesting by the orchard worker in grape cultivation activities.

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Abstract
The aim of this study was to find out the adoption of ergo stool for pruning and harvesting by the orchard worker in grape cultivation activities. Physical fitness was determined by calculating the physical parameters i.e. height, weight, BMI, body composition, VO_2 max(ml/kgxmin), Body temperature, blood pressure, pulse rate, pulse pressure(mm/hg). The research designs comprised Ergo solution were developed in department of FRM and for testing and feedback of ergo solution. one orchard was selected randomly from the orchards selected in phase- II. An ergonomic experiment was carried out on 10 respondents, selected in phase II to find the feasibility of modified and developed ergo solution. This phase was carried out in sub-stages described as follows, Design and development of Ergo stool for grape pruning and harvesting activity. An ergonomically designed sit –stand multipurpose stool was developed considering the anthropometric dimensions of the users populations and it was named as (Ergo stool for pruning and harvesting). Ergo solution for pruning and harvesting consisted of platform made up of wood. Two drawer were provided to store items such as water bottle, scaff, scateurs, blade, scissor etc. The leg of Ergo solution for pruning and harvesting were simple, strong and made up of steel. On three sides of stool, steel support was provided 5" from the floor level this helped to step on the stool. Handles made up of steel helped to step on the stool. Conclusively on the basis of results of phase II pruning and harvesting of the grapes were identified as the highly risk prone activities. So available technology used by them was modified and ergo stool was developed for these two activities.

Keywords: grape cultivation, grape pruning, grape harvesting, ergo stool, orchards workers

Introduction
Grape (*Vitis vinifera L.*) is an important fruit crop in India. Grapes are the third most widely cultivated fruit after citrus and banana. Major grape-growing states are Maharashtra, Karnataka, Andhra- Pradesh, Tamil Nadu and the north- western region covering Punjab, Haryana, Delhi, western, Uttar Pradesh, Rajasthan and Madhya Pradesh (Singh, 2010) [5]. In Haryana grapes are cultivated in an area of 111.00 (000 ha) with a total production of 1235.00 (Tons) and productivity of 11.10 (tons/ha) in 2010-11 (National Horticultural Board, Government of India). Haryana is the sixth largest producers of grapes in the country with 5.7 million ton/hectare/ year. Grape cultivation is grown under a variety of soil and climatic conditions (Shikhamany 2001) [4]. According to the International Labor Organization, the agricultural sector is one of the most hazardous sectors. Agricultural workers involve several strenuous activities like ploughing, spading, carrying, uprooting, planting, weeding, cutting, shafting, threshing, sweeping, etc. Musculoskeletal disorders were common among farmers. Grape cultivation is one of the agricultural activities. Grape cultivation involves various activities like land preparation, irrigation, manuring, pruning, harvesting, transportation etc. Many tasks such as dormant pruning, shoot suckering and crop harvesting were done repetitively by hand and could result in musculoskeletal disorders (MSD) among the workers. Pruning had also been associated with increased risk of developing cumulative trauma disorder of the wrist among workers. Vineyard rows (about 30 feet long each) was planted 8 to 12 feet apart, with about five vines per row. Pruning one vine takes about 60 seconds. Pruning work were shifts are 8 hours, with approximately 2400 cuts per hour i.e., about 60 vines per hour, or 480 vines per day (Roquelaure *et al.* 2002). Lifting and carrying of loads is typically associated with harvesting of grapes, which are usually hand harvested and carried in some type of basket or carrier to the edge of the field, where they are collected. Loads are often not heavy (10 kg or less), but the distance to be travelled is significant in many cases and over uneven terrain, which may also be wet or slippery. Training plants on trellises requires the

exertion of substantial force, a force that is increased by the weight of the vines, foliage and fruit. This force is commonly exerted through the arms, shoulders and back, all of which are susceptible to both acute and long-term injury from such overexertion. Grapes are also commonly cut from the vine during hand harvest. This cutting motion is also very frequent (hundreds of times per hour) and requires sufficient force to cause concern regarding cumulative-trauma injuries. Harvesting is often done in awkward postures and at a rapid pace. Persons typically twist and bend, bend without bending the knees and move quickly between the bush or vine and the container. Containers are sometimes placed upon the ground and pushed or pulled along with the worker. Several studies have already been done and more are on the way to develop a perfect ergo solution for pruning and harvesting of grapes. A hook was used as a supporting device for carrying fruit, is an easy solution. Various ergo-solutions have already been developed for the activities like pruning, weeding and harvesting. However, when full, the bucket had to be lifted almost at shoulder level, which is stressful. And also a small ladder allows a good working posture during harvesting. A light-weight ladder was preferred the ladder had to be moved from one place to another (lifted) so frequently. So to avoid excessive reaching and acrobatic postures: Moving the harvested tree fruit in a picking train is an efficient practice. The fruit was placed directly from the tree in a pallet box. Work is often combined with a picking platform that is used for the higher localized fruit. Meyers. *et.al* (2000) [8] found that a movable table should be used to elevate trays while weeding. Workers stood while weeding, relieving prolonged stress on back. Workers must still stoop to pick up and replace trays, but change of position was better than prolonged position. Tray was closer to worker, reducing strain from reaching. Strain reduction would improve worker performance. He found that a smaller, lighter tub that had add-on grips and weighed an average 46 pounds when full. The lower weight was easier on the back, knees and arms. The narrower width positioned the tub's center of gravity closer to the worker, which reduced stress on the back. Lighter weight and smoother bottom surface reduce the sideways forces on the knees when pushing the tub down the row. Better handles reduce pressure points on the fingers. So keeping in mind the working pattern and working conditions the present study was under taken the adoption of ergo stool for pruning and harvesting by the orchard worker in grape cultivation activities.

Materials and Methods

A sample of 10 respondents was selected purposively from the randomly selected 2 grape orchards. Physical fitness of the workers involved in grapes cultivation activity was ascertained by measuring the parameters i.e. height, weight, BMI, body composition, VO_2 max(ml/kgxmin), Body temperature, blood pressure, pulse rate, pulse pressure(mm/hg). height, weight, BMI, body composition, VO_2 max (ml/kgxmin), Ectomorphic, Mesomorphic type body, Body temperature, blood pressure, pulse rate, pulse pressure(mm/hg). The height was measured using a stadiometer. A stadiometer is a piece of medical equipment used for measuring height. The stadiometer has a measuring range. Body weight: An accurate portable weighing machine was used for the study to take the weight of the orchards workers. The subject was asked to stand straight on the balance and the weight was recorded in kg with an accuracy of 0.1kg. BODY MASS INDEX: The condition of the workers was assessed by specifying the different degrees of the underweight expressed as the body mass index(BMI),the weight and height measures was used to calculate the BMI of respondents. Weight in (kg)/ Height in (m^2) (Garrow, 1981) [2] the Body mass index was calculated using the standard formula. Accordingly, the health status was defined as follows: i) BMI 20–24.9 (normal); ii) BMI 25–29.9 (overweight); and iii) BMI ≥ 30 (obesity). Estimation of body composition was determined from skin fold thickness at four sites i.e., biceps, tricep, subscapular and supreilliac with the help of skin fold caliper by using the methods proposed by Durnin and Rahman (1967) [1]. The lean body mass was assessed with the help of the following formula.

LBM (Kg) = Body weight – Fat weight

$$\text{Fat weight} = \frac{\text{Body weight x \% fat.}}{100}$$

% fat = (4.95 /D - 4.5) x 100

Where D is body density.

Body density= 1.1599 - (0.0717 x log of sum of four skin folds)

Maximum aerobic capacity (VO_2 max) was on the basis of physical fitness is the term which denotes an individual ability to accomplish a given task in a given period of time aerobically with maximum utilization of oxygen possible. It is also Known as maximum aerobic capacity and abbreviated as VO_2 max. The maximum aerobic capacity is considered as the best measures for the individual cardio respiratory fitness or capability of doing work Varghese *et al.* (1994) [6]. The formula was based on the relationship between age and body weight as they have great influence on VO_2 max.

(VO_2 max) = VO_2 (1/min) = 0.023 × body weight (Kg) – 0.034 × age (year) + 1.652

(VO_2 max) (Ml/kg × min) = VO_2 max (1/min/ Body weight (Kg.) × 10000

Blood pressure and pulse rate was standardized through sphygmomanometer and stethoscope and digital blood pressure, body temperature was measured by using clinical thermometer, Body temperature for three minutes- not above 99%, blood pressure-120/80± 10, and Heart rate-70-90 b-min^{-}.

Pulse pressure = Systolic pressure- Diastolic pressure

Average mean pressure = Diastolic pressure + 1/3rd of pulse pressure

Design and development of Ergo stool for grape pruning and harvesting activity

An ergonomically designed sit –stand multipurpose stool was developed considering the anthropometric dimensions of the users populations and it was named as (Ergo stool for pruning and harvesting)

Design consideration of the (Ergo stool for pruning and harvesting)

- **Use of alternate posture**-To allow alternate posture during the activity an appropriate approach is sit and stand stool. Ergo solution for pruning and harvesting was designed that user can move left and right easily.

- **Storage supplies**- All the supplies, tools should be within the easy reach of workers hence to be provided on the work surface. The drawers were provided in the (Ergo solution for pruning and harvesting for the storage of supplies.
- **Easy to use** - Handle was provided so that it can be easily moved from one place to another.

Ergo solution for pruning and harvesting consisted of platform made up of wood. Two drawer were provided to store items such as water bottle, scaff, scateurs, blade, scissor etc. The leg of Ergo solution for pruning and harvesting were simple, strong and made up of steel. On three sides of stool, steel support was provided 5” from the floor level this helped to step on the stool. Handles made up of steel helped to step on the stool

Design specification of developed (Ergo stool for pruning and harvesting)

- Height – 22”
- Width - 24 ”
- Length- 18”
- Handle length- 18”
- Length of rack for storing tool accessories-21”
- Step height – 5”
- Drawers (i) L×W×H=17×16×6
  (ii) L×W×H=16×4×5

(Ergo stool for pruning and harvesting)

Plate 1: Design specification of developed

In the present context, feasibility has been defined as the extent to which workers have considered the (Ergo stool for pruning and harvesting and grape pruning secateurs) in terms of different attributes namely i.e profitability, physical compatibility, cultural compatibility, simplicity, triability, grip fatigue, physical stress factor, work output, tool factor and acceptability. The responses of the workers were recorded on 5 Point scale. The quantifying scores for positive statements were quantified by assigning scores i.e.

- Strongly agree-5
- Agree-4
- Undecided -3
- Disagree-2
- Strongly disagree-1

For quantifying negative statements the scoring was as follows-

- Strongly agree-1
- Agree-2
- Undecided-3
- Disagree-4
- Strongly disagree-5

The mean scores were calculated for each category of statements and attained score were calculated by summation of the mean scores of different statements under each heading. The percentage of maximum attainable score was calculated by using the following formula:

$$\text{Feasibility index: } \frac{E\ (P+Pc+Cc+Sc+Tc+Gf+PF+Wo+Tf+Ac)}{P\ (P+Pc+Cc+Sc+Tc+Gf+PF+Wo+Tf+Ac}\times 100$$

Where,
E (P+Pc+Cc+ Sc+ Tc+ Gf+ PF+ Wo+ Tf+ Ac) is excepted score of profitability, physical compatible, cultural compatible, simplicity, triability, grip fatigue, Physical stress factor, work output, tool factor, acceptability.
P(P+Pc+Cc+ Sc+ Tc+ Gf+ PF+ Wo+ Tf+ Ac is perceived score of profitability, physical compatible, cultural compatible, simplicity, triability, grip fatigue, physical stress factor, work output, tool factor, acceptability

Results and Discussion

Physical characteristics of workers involved in grape cultivation

Mean height and weight of grape workers involved in grape was 159.9 cm and 64.2 kg respectively. Body mass Index (BMI) was observed as 21.8 Kg/m^2. Fat percentage was worked out to be 29.9 per cent. Hence LBM (Lean body mass) was 44.1 kg with variation of ±19.3kg. Aerobic capacity (VO_2 max) was found to be 31.8 ml/ kg ×min exhibiting that the subjects were having good health

Table 1: Personal profile and health status of the selected respondents (n=15)

Physical Characteristics		Mean ± SD
Height(cm)		159.9± 8.8
Weight(Kg)		64.2±4.7
BMI (kg/m^2)		21.8±1.1
Body composition	Fat percentage (%)	29.9±5.9
	Lean body mass(kg)	44.1±19.3
Vo_2 max(ml/kg.×min)		31.8±6.3

Health status of workers involved in grape cultivation

In order to avoid any experimental error and to maintain the uniformity in data, only those workers were selected for the experimental study that had high average to good health status. It was clear from the table 2 that the mean body temperature was 98.6±0.33, blood pressure was systolic (mm/Hg)125.6±10.3, diastolic (mm/Hg) 80.3±4.8, pulse rate was 86.8±9.3bpm and pulse pressure was 45.7±4.2 mm/Hg. All the variables were in the normal range.

Table 2: Health status of workers involved in grape cultivation (n=15)

Variables of health status	Observed values	Recommended value	Category
Body temperature(^{0}F)	98.68±0.33	98.4degree F	Normal
Blood pressure : Systolic(mm/Hg) Diastolic(mm/Hg)	 125.69±10.36 80.38±4.89	 120mm/Hg 80mm/Hg	Normal
Pulse rate(bpm)	86.8±9.36	70-80bpm	Normal
Pulse pressure (mm/Hg)	45.7±4.2	30-50mm/Hg	Normal

Development of ergo solution i.e Ergo stool for pruning and harvesting Acceptability of Ergo stool for pruning and harvesting by grape orchard workers.

The Acceptability of Ergo stool for pruning and harvesting was obtained from 10 grape orchard workers. Ranks were computed on the basis of mean score obtained and has been presented in table 3

Table unveils that "liked the appearance', acceptable for use got 1st rank with mean score 3. "Maintained comfortable body posture at standing position' and "shoulder pain can be avoided' got 2nd rank with mean score 2.9. 'Good replacement to the existing tool secured 3rd rank with mean score 2.7 'Convenient height of 'Ergo stool for harvesting and pruning "no pain and cramps in the upper region of body after performing the activity got rank 4 with mean score 2.6. Followed by convenient cleaning process with 5th rank and mean score 2.5 and "lesser discomfort in mid back region' secured 6th rank with mean score of 2. Similarly Hermans *et al*. (2009) developed a cart and reported that trained, grapevine shoots reach a height of 7 feet or more. The fruit zone- range from 2 to 6 feet above ground level, again depending upon training system. These height results in many awkward hand, wrist, and back postures while working. Using a vineyard cart may improve posture by letting workers sit while carrying out different operations such as pruning and harvesting. Although the carts are reasonably effective in preventing MSDs, they work satisfactorily; the ground is relatively flat and hard. Walters (1996) reported that the risk of hand and wrist injuries be avoided with good work habits. Reducing the hand and wrist injuries is assigning different responsibilities to workers on a given work day taking periodic breaks; working at a slower pace and using ergonomically matched tools.

Table 3: Acceptability of ergo stool for pruning and harvesting by the orchard workers (n=10)

S. No	Parameters	Mean score	Rank
1	Liked the appearance	3.0	I
2	Convenient cleaning process	2.5	V
3	Convenient height of ergo stool for pruning and harvesting	2.6	IV
4	Maintained comfortable body posture at standing position	2.9	II
5	Shoulder pain can be avoided	2.9	II
6	Lesser discomfort in mid back region	2.0	VI
7	No pain and cramps in the upper region of body after performing the activity	2.6	IV
8	Good replacement to the existing tool	2.7	III
9	Acceptability for use	3.0	I

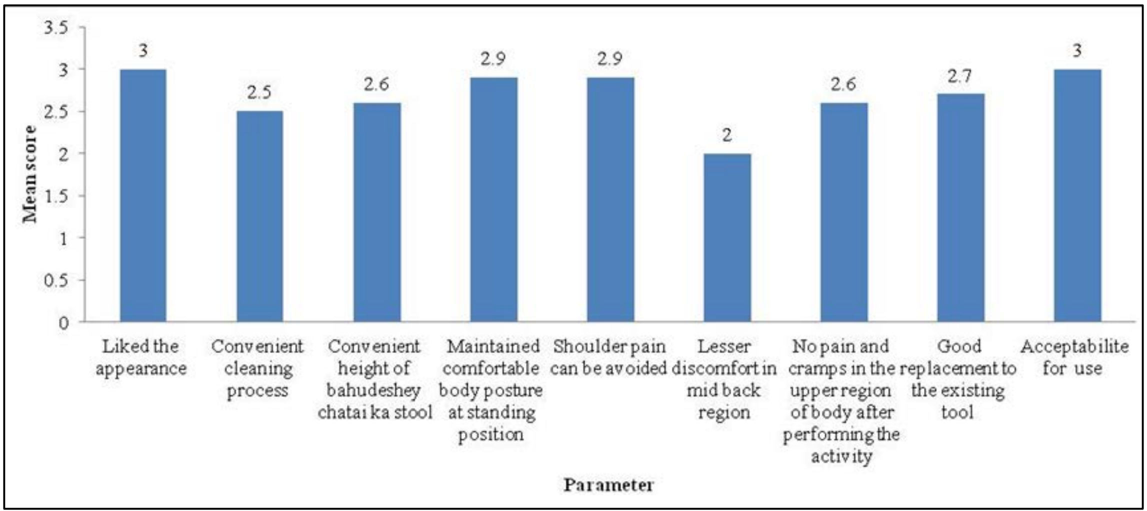

Fig 1: Acceptability of ergo stool for pruning and harvesting by the orchard workers

Feasibility of Ergo stool for pruning and harvesting

Tables 4 depicts the feasibility of Ergo stool for pruning and harvesting in terms of profitability, physical compatibility, cultural compatibility, simplicity, traibility, grip fatigue, physical stress factor, work output, tool factor and acceptability.

Profitabiltiy: Data presented in the table 4 showed that cent percent of the respondents considered a Ergo stool for pruning and harvesting profitable feasible technology

Physical compatibility: Most of the respondents 30 % considered the Ergo stool for pruning and harvesting as feasible and while 70% respondents considered it as somewhat feasible, technology for grape pruning, in terms of physical compatibility

Cultural compatibility: For cultural compatibility 80 percent of the respondents considered it as feasible, 20 percent respondents considered it as somewhat feasible technology

Simplicity: Cent percent of the respondents considered Ergo stool for pruning and harvesting as most Simple feasible technology for pruning of grapes

Triability: Cent percent of the respondents considered *as* Ergo stool for pruning and harvesting feasible technology for traibility

Grip fatigue: Table 4 further highlighted that for 60 percent of the respondents Ergo stool for pruning and harvesting was most feasible and for 40.0 percent respondents it as feasible technology for reducing the grip fatigue

Physical stress factor: Table 4 revealed that cent percent of the respondents considered Ergo stool for pruning and harvesting as feasible technology for grape pruning for reducing physical stress

Work output: Majority of the respondents (90%) considered Ergo stool for pruning and harvesting as feasible, 10 percent respondents consider it as most feasible technology, to increase the work output.

Tool factor: All of the respondents considered it as most feasible technology in terms of tool factor

Acceptability: Cent percent respondents considered Ergo stool for pruning and harvesting *as* most feasible technology for the acceptability

On the whole respondents 27 percent considered Ergo stool for pruning and harvesting as most feasible 54 percent respondents considered it as feasible, 19 percent considered it as somewhat feasible**,** technology for pruning of grapes. Skelton (2007) reported that hand-picking grapes in vineyards cause a lot of awkward back postures due to the low positions of the grapes. To avoid excessive reaching an up-turned light-weight crate can be used. The handle, a half broom stick, is attached to reduce bending of the back when moving the crate. A crate can also be used to bring the bucket or other basket to a higher level. Similarly old orchards sledge can be used as a table to put the bucket or crate on. Stooped postures are avoided. And also a hook, used as a supporting device for carrying fruit, is also an easy-to-use solution. However, full bucket has to be lifted almost at shoulder level, which is stressful.

Table 4: Feasibility of Ergo stool for pruning and harvesting (n=10)

S. No	Feasibility	Most feasible	Feasible	Some-what feasible
1	Profitability	-	10(100)	-
2	Physical compatibility	-	3(30)	7(70)
3	Cultural compatibility	-	8(80)	2(20)
4	Simplicity	10(100)	-	-
5	Triaibility	-	10(100)	-
6	Grip fatigue	6(60)	4(40)	-
7	Physical stress factor	-	10(100)	-
8	Work output	1(10)	9(90)	-
9	Tool factor	-	-	10(100)
10	Acceptability	10(100)	-	-
	Overall n=100	27(27.0)	54(54.0)	19(19.0)

Feasibility index of Ergo stool for pruning and harvesting

Feasibility index was assessed in terms of profitability, physical compatibility, cultural compatibility, simplicity, triability, grip fatigue, physical stress factor, work output factor, tool factor and acceptability and presented in table 5

It was clear from the table that simplicity and acceptability got first rank with feasibility index of 100%, physical stress factor and grip fatigue got 2nd rank with feasibility index 92 percent followed by work output with feasibility index 82 percent and 3rd rank. Profitability and triability secured feasibility index of 80 percent and 4th rank. Culture compatibility got 5th rank with feasibility index of 76 percent and tool factor got 6th rank with feasibility index 60 percent. The last rank was for physical compatibility with least feasibility Index of 66 percent. Overall feasibility index of Ergo stool for pruning and harvesting was 82.8%, indicating that it was acceptable to the workers. Peppelman *et al.* (2006) reported that comparing pick-train, hydraulic pick-lorry by using a pick-bucket, conveyor harvester and the adjustable picking platforms (also called pluk-o-trac), the adjustable picking platforms introduced the least unhealthy working arrangements. The pick-train was the cheapest harvesting method and the workers have less static postures. The working position on the conveyor harvester can be improved when harvesters use a crate or small ladder to pick the apples out of the top of the trees. For the picking performance it was important that the conveyor harvester could be used in combination with another harvest method. IDEWE (External service for prevention and protection at work (non-profit) found that to transport the fruit baskets an adapted wheelbarrow was used. Lifting and carrying the baskets were reduced. Wheel barrow was the better working height while emptying the fruit basket, the picker no longer has to bend the back so excessively. Thiyagarajan *et al.* (2013) reported that heart rate and oxygen consumption rate of the sugarcane knives varied from 132.55 to 138 beats min-1 and 1.171 to 1.253 L min-1, respectively. The energy cost of sugarcane harvesting knives, varied from 24.45 to 26.16kJ min-1 respectively. The values of percent maximum aerobic capacity (VO2 maximum) and work pulse for sugarcane harvesting knives were much higher than that of the acceptable workload (AWL), limits of 35, the sugar cane harvesting knife (H1) ranked as I in terms of minimum value of heat rate (132.55 beats min-1), energy cost of work (24.45 KJ min-1), acceptable work load (58.14%), over all discomfort rate (moderate discomfort) and Body part discomfort score (29.39) when compared with other three models (H2, H3 and H4) of sugarcane harvesting knives.

Table 5: Feasibility index of Ergo stool for pruning and harvesting (n=10)

Feasibility	Total	Feasibility index	Rank
Profitability	40	80	IV
Physical compatible	33	66	VII
Cultural compatible	38	76	V
Simplicity	50	100	I
Triability	40	80	IV
Grip fatigue	46	92	II
Physical stress factor	46	92	II
Work output factor	41	82	III
Tool factor	30	60	VI
Acceptability	50	100	I
	414	(82.8%)	

Conclusion

- Mean height and weight of grape workers involved in grape cultivation was 159.9 cm and 64.2 kg respectively. Body mass Index (BMI) was observed as 21.8 Kg/m^2. Fat percentage was worked out to be 29.9 per cent. Hence LBM (Lean body mass) was 44.1 kg with variation of ±19.3kg.
- On the basis of results of Phase II pruning and harvesting of the grapes were identified as the highly risk prone activities. So available technology used by them was modified and ergo solution was developed for these two activities. ergo stool for pruning and harvesting activity was developed the acceptability and feasibility of ergo stool for pruning and harvesting was assessed.
- The acceptability of ergo stool for pruning and harvesting highlighted that appearances and acceptable for use got highest rank.
- Feasibility index of ergo stool for pruning and harvesting was 82.8% indicating that it was acceptable to the user.

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