Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(2): 2291-2295
Received: 09-01-2019
Accepted: 13-02-2019

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Modification of dryland weeder to increase suitability and the ease of operation

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Abstract
Dry land weeder is used to remove weed between two rows in push pull mode, work being performed in the standing posture. Considering the demand to increase the suitability and the ease of operation, the dryland weeder was modified on the basis of anthropometric data of male users. The handle height, length, grip diameter etc. were modified based on the relevant anthropometric dimensions. Ergonomic evaluation of developed dryland weeder was carried out with six male subjects. The EER was decreased by 14.5 per cent. The work pulse was also decreased. The field capacity and weeding efficiency were increased by 30 % and 6%, respectively. The overall discomfort rate was also decreased by 33.8 per cent.

Keywords: Modification, dryland weeder, increase suitability, operation

Introduction
The weeds have always been problems in the cultivation of crops as they lower the yield and quality. Weeds also may directly reduce profits by hindering harvest operations and producing chemicals that are harmful to crop plants. Weeds left uncontrolled may harbour insects and diseases and produce seeds and rootstocks. Weeds can also be potential carriers of infections, fungus and other diseases, which can contaminate the crops. (Biswas *et. al*., 2000) [4]. Weeds are unwanted and undesirable plant that interfere with utilization of land and water resources and thus adversely affect crop production and human welfare. Weeds compete with the crops for water, soil nutrients, light and space (i.e.CO_2) thus reduces crop yields. The most common methods of weed control are mechanical, chemical, thermal, biological and traditional methods. Nganilwa *et. al.* (2003) [5] opined that a farmer using only hand hoe for weeding would find it difficult to escape poverty, since this level of technology tends to perpetuate human drudgery, risk and misery.
Dry land weeder is used to remove weed between two rows in push pull mode, work being performed in the standing posture. As per feedbacks of users, it was noteworthy that pushing and pulling was not with ease. It was seemed to be somewhat awkward. Also, handle height and width were too more to use it comfortably. It was also necessary to incorporate anthropometric parameter of workers in modification. Hence, in order to make available dry land weeder user friendly, the research work on modification and testing of dry land weeder was undertaken.

Material and Methods
The existing dryland weeder consisted of roller with pegs fitted on the square bars. The diameter of the roller was 150 mm, V shaped blade with 58^0 was fixed just below the roller. The handle was made from circular pipes having length, working height and grip diameter 1160 mm, 1250mm and 35 mm, respectively. The total weight was 7.2 kg. The schematic sketch and photograph of existing dry land weeder is shown at Fig.1 and Plate 1.

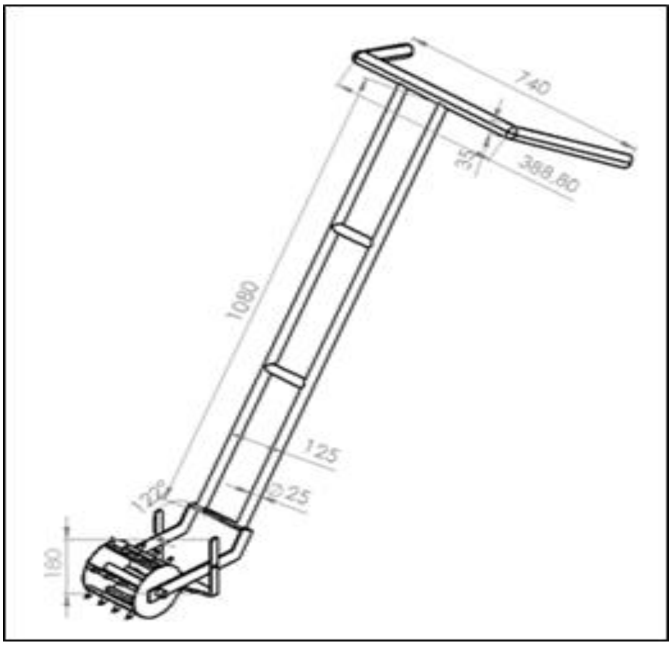

Fig 1: Schematic view of existing dry land weeder

Plate 1: Photograph of existing dry land weeder

Ergonomic considerations

Different parts of existing dry land weeder viz; handle height, cross handle bar length, handle diameter, length, grip diameter were modified, based on anthropometric dimensions of agricultural workers of Maharashtra.

The ergonomic design considerations for modifying dryland weeder are given in Table 1

Table 1: Ergonomic design consideration for manually operated dry land weeder

S.N.	Dimension	Anthropometric consideration
1.	Handle height	0.7 of the 95th percentile acromial height of male worker.
2.	Cross handle bar length	95th percentile elbow-elbow breadth of male worker.
3.	Handle grip diameter	95th percentile middle finger palm grip diameter of male worker. 5th percentile grip diameter (inside) of male worker.
4.	Handle grip shape	Desirable shape of handle grip

Theoretical considerations

The following theoretical design criteria were applied for the design of various part of weeder.

Power to operate

$$HP = \frac{push\ (kgf) \times speed\left(\frac{m}{s}\right)}{75}$$

Cutting blade

Size of cutting blade

V-blade; $\left(\frac{W + w_1}{2}\right) \times d \times unit\ draft = push\ or\ pull$

Where, W = width of the cutting blade (opposite to direction of travel)

W_1 = width of cutting blade (direction of travel)

Handle length

Length was calculated based on average standing elbow height of male operators

$$\tan(\theta_h) = \frac{l_h}{l_c}$$

Where,

l_h = average standing elbow height of male operator.

l_c = distance of wheel center from the operator height of in operating condition.

Number of pegs provide on roller

Numbers of pegs provided on each roller were calculated as follow

$Circumference = \pi \times D$, D = roller diameter

$Number\ of\ pegs\ on\ roller = \left(\frac{\pi \times D}{x_1}\right) \times \frac{L}{x_2}$

L = length of roller, x_1 = length along circumference

x_2 = distance between two pegs

Ergonomic evaluation

Six male subjects were participated in ergonomic evaluation. The average values of age, stature and weight of subjects were 21.16, (±0.75) 173.5 cm (±8.16) and 72 kg (±16.34), respectively. The details of selected subjects are shown in Table 2.

Table 2: Details of subjects participated in the study

Sl. No.	Subject code	Age, years	Stature, cm	Body weight, kg
1	AP	21	189	59
2	AB	20	173	75
3	SP	22	168	79
4	RV	21	166	57
5	SJ	22	171	62
6	NS	21	174	100
Mean		21.16	173.5	72
SD		0.75	8.16	16.34

Above mentioned six subjects were calibrated in the laboratory to develop relationship between heart rate (HR) and oxygen consumption rate (OCR) and thereby to determine maximum aerobic capacity individually. The standard protocol was used for the purpose. Computerised tread mill was used as loading device while K5b2 was used for measurement of physiological parameters.

The aerobic capacity was assessed through conducting sub maximal tests on computerized treadmill ergometer. A target heart rate was taken as approximately 75% of the age predicted maximum heart rate. The maximum heart rate attainable by the subject was computed by the following relationship (Astrand, 1960) [3].

HR (max) = 220 – (age in years)

Every test was continued up to the fully exhausted period duration test or subject has attended the 75% of age predicted maximum heart rate, whatever was reached earlier. Correlation between heart rate and oxygen consumption rate at specified sub maximal workloads were developed and the regression line was extrapolated to the age predicted maximum heart rate and VO_2 corresponding to HR max was noted as maximum aerobic capacity. The calibration chart is shown in the Fig. 2.

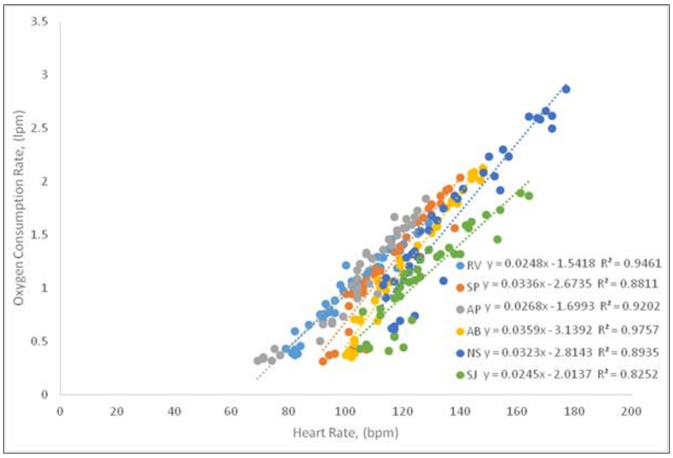

Fig 2: Calibration chart of subjects

Results and Discussion

Ergonomic design consideration for the machine

Six subjects were calibrated in the ergonomics laboratory. The heart rates and corresponding oxygen consumption rates of the subjects were measured by using energy measurement system (K_5b2) while subjects running on treadmill ergometer at sub maximal loads to get the relationship between the heart rate and oxygen consumption. The details of subject's maximum heart rate and VO_2 max are furnished in Table 2.

Table 3: Maximum aerobic capacity (VO_2) and max heart rate of selected subjects

S. N.	Subject code	Max heart rate, beats/min	Max aerobic capacity (VO_2max), l/min
1	AP	199	3.6
2	AB	200	4.04
3	SP	198	3.9
4	RV	199	3.4
5	SJ	198	2.8
6	NS	199	3.6
	Mean	198	3.59
	SD	0.75	0.43

The mean value of Max heart rate, beats/min and Max aerobic capacity (VO_2max), l/min of six subjects were 198 (±0.75) and 3.59 (±0.43), respectively.

Ergonomic considerations

The previous dry land weeder was not designed as per the anthropometric dimensions of workers. The handle height, handle diameter as well as handle width of dry land weeder should be changed as per the respective anthropometric dimensions of workers. The anthropometric dimensions of male workers were used for the modification dry land weeder. The detailed anthropometric considerations are given in previous section. The various dimensions modified of dry land weeder viz., handle height, handle diameter, handle width and length of handle were modified on the basis of anthropometric data as follows.

Handle height

The anthropometric dimension useful for consideration of handle height was acromial height. The 0.8 of the 5^{th} and 0.7 of the 95^{th} percentile value of the acromial height of male workers of Maharashtra were 1255 mm and 1453 mm respectively. Hence, average range adopted for handle height was between 938 - 1162 mm. The adjustable handle height was provided.

Handle diameter

The dimensions of middle finger palm grip diameter and grip diameter (inside) of men workers of Konkan region are used to design grip diameter of handle. The diameter of the grip should be such that while holding the grip, the operator's longest finger should not touch the palm. At the same time, the grip should not exceed the internal grip diameter. 95^{th} percentile middle finger palm grip diameter is the lower limit i.e. 38 mm and 5^{th} percentile grip diameter (inside) i.e. 39 mm of the male worker was to be considered as the upper limit. Hence, the handle diameter of modified dry land weeder provided with rubber grip was taken as 37 mm to reduce the discomfort to the palms of worker during operation.

Handle width

The anthropometric dimension useful for consideration of handle width was elbow-elbow breadth. The desirable position of holding the cross handle bar should be in the line of arms. Hence the handle width was considered i.e. 450 mm as per the dimensions of 95^{th} percentile elbow to elbow breadth of men workers. The handle width in the existing dry land weeder was 630 mm. The handle width adopted for dry land weeder 510 mm as considering 60 mm allowance for movement (30 mm on each side).

Length of handle

Length of handle for existing dry land weeder was 1240 mm. In modified dry land weeder it was increased to 1420 mm.

0.7 of 95th percentile of acromial height, mm = 1024,

Diameter of roller, mm = 150,

Radius = 75 mm

Subtracting roller radius from 0.7 of 95th percentile of acromial height, handle height was 949 mm.

Considering angle of 45˚,

Length of handle, $\cos 45 = \frac{949}{length\ of\ handle}$

Length of handle = 1420 mm

Theoretical considerations

In theoretical design, power developed by operator, length of handle, number of pegs and cutting blade were considered. Push force required to operate modified dry land weeder was 64.7 N. The 5th percentile value of push strength was 122 N and 30% of this value was 36.5 N. As this is intermittent operation i.e., push and pull operation, so continuous push force was not applied to weeder. Hence, this force was acceptable. Width of cutting blade was kept same i.e.150 mm, handle length was increased to 1420 mm and number of pegs were kept same as existing dry land weeder.

Weight of machine

As per the study, ergonomic design in handle height, handle diameter, handle width, modification of roller were reduced the weight of machine. The weight of existing dry land weeder was 7.2 kg. The weight was reduced after modification and it was observed to be 5.1 kg. Hence, the weight was reduced by 29%.

The schematic sketch and photograph of modified dryland weeder is shown in Fig 3 and Plate 2.

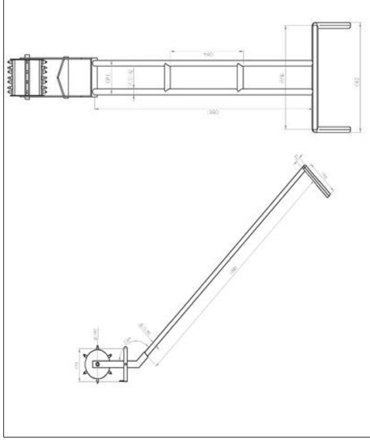

Fig 3: Schematic view of modified dryland weeder

Plate 2: Photograph of modified dryland weeder

Comparative ergonomic evaluation

A comparison of all parameters of ergonomic and performance evaluation for the existing and modified dry land weeder are presented in Table 3.

Table 4: Comparative of ergonomic and performance evaluation

S. N.	Parameters		Existing weeder	Modified weeder
1.	Working heart rate, beats/min		122.78 (±12.38)	117 (±11.14)
2.	Oxygen consumption rate, l/min		1.30 (±0.18)	1.11 (±0.32)
3.	Energy expenditure rate, kJ/min		27.3 (±3.94)	23.3 (±6.71)
4.	Grading of work		Moderately heavy	Moderately heavy
5.	Oxygen consumption in per cent of VO_2 max		39.06 (±5.87)	30.04 (±2.33)
6.	Work pulse Δ HR, beats/min		49.47 (±16.39)	38.5 (±13.48)
7.	Overall discomfort ratings (ODR)		7.3 (±0.81)	4.8 (0.41)
8.	Body part discomfort score (BPDS)		39 (±9.86)	11.5 (±2.17)
9.	Force required, kg	Push	-	6.6
		Pull	-	2
10.	Field capacity, ha/h		0.007	0.0092
11.	Field efficiency, (%)		77.24	81.24
12.	Weeding efficiency, (%)		84.36	89.44

The working heart rate values were 122.78 and 117 bpm with existing and modified dry land weeders, respectively. The OCR values were 1.3 and 1.1 for existing and modified dry land weeder resulting EER was 27.3 kJ/min and 23.3 kJ/min, respectively. Similarly for existing and modified dry land weeder the work pulse (Δ HR) values were 49.47 bpm and 38.5 bpm, respectively. Comparing those two weeders considering subjective rating scales ODR values were 7.3 and 4.8 for existing and modified dry land weeder. Also, BPS scores for existing and modified dry land weeder were 39 and 11.5, respectively.

The field capacities for existing and modified dry land weeder were 0.007 ha/h and 0.0092 ha/h, respectively. The field efficiencies were 77.24% and 81.24%, respectively for existing and modified dry land weeder. The weeding efficiencies were 84.36% and 89.45%, respectively for existing and modified dry land weeder.

Conclusion

1. The EER was decreased by 14.5 per cent in modified dryland weeder.
2. The work pulse was decreased by more than 10 beats per min in modified dryland weeder.
3. As comparison of existing dryland weeder, the field capacity and weeding efficiency in modified dry land weeder were increased by 30 % and 6%, respectively.
4. The overall discomfort rate was also decreased by 33.8 per cent in modified dry land weeder.

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