Ciência Rural, Santa Maria, v.47: 06, e20160743, 2017 http://dx.doi.org/10.1590/0103-8478cr20160743

ISSNe 1678-4596
BIOLOGY

Design requirements of a human-powered planter

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ABSTRACT: *This study aimed to establish client and design requirements of a human-powered planter. A total of 13 client requirements and 13 design requirements were established for prioritizing planter performance, thus providing benefits to users.*
Key words: *machinery design, precision planter, agricultural machinery.*

Requisitos de projeto de uma semeadora acionada por força humana

RESUMO: *Este trabalho objetivou estabelecer os requisitos de clientes e de projeto de uma semeadora à tração humana. Foram estabelecidos 13 requisitos de clientes e 13 requisitos de projeto, priorizando o desempenho da semeadora, proporcionando benefícios aos seus usuários.*
Palavras-chave: *projeto de máquinas, semeadora de precisão, máquinas agrícolas.*

Planters with various characteristics, such as good seeding quality (TEIXEIRA et al., 2009) and use of human traction (STEFANELLO et al., 2014), are required for use in small holders (SH). Farmers usually suffer from muscle pain after performing various agricultural activities, particularly those that require physical labor (GEMMA et al., 2010). Moreover, farmers are not technologically advanced and have low investment capacity (ROMEIRO FILHO, 2012). Methodologies (BACK et al., 2008) can be deployed throughout different phases to overcome the abovementioned obstacles, namely, informational design phase (for identifying client needs and converting them into specifications); conceptual phase (for elaborating a functional structure with functional solution principles and conceptual development) (STEFANELLO et al., 2014); and embodyment and detailed phase (layout, materials, manufacturing, and assembly processes, components and technical documentation). The existing gap in this field of expertise can be bridged by designing human traction planters. This study aimed to obtain client requirements (CR) and design requirements (DR) for a human-powered planter used for no tillage and conventional seeding of maize and beans to meet the small holders (SH) needs.

Bibliographic research was conducted along with an analysis of similar technical systems and specialist's consultation to identify both the customer's needs and requirements. The functional accuracy and the desirable and undesirable aspects cited below were considered the most important: production, manufacturing characteristics, assembly, availability of preformed components and materials, marketing, advantages of using such planter, acquisition costs and purchase motivation, usage, sowing problems, characteristics and operational aspects, regulation and maintenance. Data were collected from 184 SH in the municipalities of Canguçu, Herval, Jaguarão, Pelotas and São Lourenço do Sul (STORCH et al.,

Received 08.08.16 Approved 02.22.17 Returned by the author 04.13.17
CR-2016-0743.R1

2004; TEIXEIRA et al., 2009; MACHADO et al., 2010). Customer needs (CN) that were identified throughout the life cycle were converted into CR (REIS & FORCELLINI, 2006a), subsequently valued by a Mudge Diagram (SANTOS et al., 2008; FRANTZ et al., 2015), and finally converted into DR.

Farmers generally use portable manual planters in conventional maize and bean sowing. The income and willingness to invest in equipment is diverse and the farming land is generally smaller than 10 ha. Corn and beans, partly intended for subsistence, do not entirely reflect their financial value. Thus, manufacturing cost was equated with the gain in technical performance (suitable crop stands) and not entirely with crop revenue. Seeds used are of recommended cultivars, home grown seeds, and not recommended (beans), possibly classified by size, depending on the origin and availability of equipment. A suitable machine should sow more than one crop with precision and minimal seed damage while properly sowing them in the soil at regular depths (REIS & FORCELLINI, 2006b). EMATER/RS (2013-Personal Report) and EMBRAPA (2013-Personal Report) report deficient population densities of those crops.

Spacing between sowing lines should allow for equipment transit while weeding, fertilizing, and spraying. Despite requiring larger spacing, this allowed a more equidistant plant distribution as well as increased water, nutrients, and sunlight absorption (ARGENTA, et al., 2001). The planter must be regularly, easily, and intuitively adjusted to avoid incorrect regulation. Sowing, assembly, and disassembling of seed drill should be easy and quick without injuring the farmer.

Safety encompasses accidents and occupational health problems (ergonomic and farmer energy demand). Energy required to physically sow can be determined on the basis of a person's physical condition. According to ALMEIDA & SILVA (1999), continuous groove opening is not preferred as it requires superhuman effort (735 N). Punchers offer an alternative (FRABETTI et al., 2011), corroborated by the massive use of portable manual planters in no-tillage fields. Mass of seed drills affects the health and safety of the person operating it and thus must be dimensioned in observance of such restrictions.

To avoid compromising on the crop's quality or equipment's durability and performance, the maintenance of the equipment should be quick, easy, and inexpensive. The planter should be durable to avoid reinvestment. Its components must withstand use (abrasion, impact, and twisting) under various soil conditions (slopes, bumps, depressions, presence of stone, compaction, vegetation cover, or other adversities). At the time of sowing, tools are generally unavailable, thus requiring that the adjustment and assembly of the sowing machine is performed without its use. Several companies are able to manufacture and assemble seed drills with traditional components, having the equipment and professionals educated locally, allowing a technological exchange. However, some workshops and blacksmiths adopt less precision, thus requiring a design that can be manufactured using simpler and less advanced machines/tools operated by low educated staff. Tailoring design to these necessities would facilitate the decentralization of equipment manufacture, thus favoring its acquisition.

The following CNs were converted to 13 CR (Table 1): simple manufacturing, manufacturing feasibility in workshops and blacksmiths, using common standardized processes and materials in addition to reduce the number and complexity of components; low cost for feasible acquisition; easy adjustment by less skilled farmers; toolless assembly to facilitate maintenance and adjustments; operator's safety, thus allowing proper user posture, minimal effort in operation, absence of sharp corners and edges, and protected moving components; mass and accessories easily transported by a single person; metering precision, seeds singulation with minimum doubles and failures; seed deposition precision at regular depth and distance patterns between seeds, according to agronomic requirements; minimizing seed damage, safeguarding germination and emergence of seedlings; reduced maintenance, requiring less lubrication and component replacement; regular maintenance with low cost lubricants and spare parts. Easy lubrication, assembly and disassembly with less tools; durable, mechanically resistant to abrasion, avoiding frequent replacement.

CRs evaluation emphasized on the importance of functionality, ease of use, and maintenance. The better ranked CRs refer to metering accuracy, deposition accuracy, and seed damage in accordance with REIS & FORCELLINI (2006a) and VIANNA et al. (2014). The worst rated; however, disagree with the facilitated regulation and easy maintenance to which they attributed less importance, whereas REIS & FORCELLINI (2006a) ranked ease of regulation at the seventh position. Divergences can be attributed to the different clients. Supporting the present study, FRANTZ et al. (2015) gave greater importance to the final quality of the operation which, in this case, depends on the first three CRs, followed by acquisition cost, tool-less assemblies, and reduced

Table 1 - Client requirements valued and categorized by the Mudge Diagram and design requirements for a human-powered planter.

Sequence	Score	Category* (%)	CR**	DR***
1º	46	10 (22,1)	To have metering accuracy	Longitudinal distribution of seeds
2º	45	10 (21,6)	To have deposition accuracy	Seed deposition
3º	34	8 (16,4)	To cause minimal seed damage	Seed damage
4º	26	6 (12,5)	To be easy to adjust	Adjustment duration
5º	16	4 (7,7)	To have easy maintenance	Maintenance duration
6º	13	3 (6,3)	To have low acquisition cost	Production cost
7º	8	2 (3,9)	To have toolless assemblies	Manual assemblies
8º	7	2 (3,8)	To have reduced maintenance	Interval between maintenance
9º	5	1 (2,4)	To be easy to conduct	Standardized standard materials
10º	3	1 (1,4)	To have low cost maintenance	Maintenance cost
11º	3	1 (1,4)	To have simple manufacturing	Usual manufacturing processes
12º	1	1 (0,5)	To be safe to the operator	Total mass
13º	1	1 (0,5)	To be durable	Lifespan

*CRs Division into categories from 1 to 10 according to relative importance.
**CR: Client requirements: short phrases composed of the verbs "to be" or "to have" followed by one or more nouns.
***DR: Design requirements: parameters, physical quantities, functions, and constraints. Each DR may be associated with one CR or several and vice versa.

maintenance. Primarily, machines must address the technical aspects reported by FRANTZ et al. (2015).

Thirteen DR have been established (Table 1), which satisfactorily meet the CN and CR. Among these, 7 coincide with those listed by VIANNA et al. (2014) for seed meters, except production and maintenance costs and maintenance intervals and duration. TEIXEIRA (2008) considers the manufacturing costs, sowing accuracy, useful life and frequency, and maintenance time identical for mechanically and animal powered planters. With the exception of DR being "easy to conduct," the remaining 12 were also predicted by REIS & FORCELLINI (2006b) for seed meters. Despite their often similar DRs during the design phases, different equipment may present differing degrees of importance, depending on each design's intent and client.

CR evaluation gave the planter's functionality and ease of use greater importance than its constructive or economic aspects, evidencing that machine performance during sowing should be prioritized throughout the design. The valued CR list and the DR list allow the seeder's design process to evolve while constantly guiding the customers' needs.

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