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Ergonomics — Application of ISO 11226, the ISO 11228 series and ISO/TR 12295 in the agricultural sector

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 3, *Anthropometry and biomechanics*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Agriculture is by far the biggest working sector in the world. It is estimated that 2,6 billion people or 40 % of the world's population are farmers. Agriculture is one of the most hazardous sectors in both the developing and the developed worlds. Work-related musculoskeletal disorders (WMSDs) are the most common work-related diseases in farmers. In Europe more than 50 % of farmers report disorders of their lower back or limbs related to their working conditions. WMSDs are caused mainly by manual handling, heavy physical work, awkward postures and repetitive movements. Increasing attention is being drawn to the application of practical actions in agricultural settings to help reduce work-related accidents and illness and WMSDs in particular. ISO 11226, the ISO 11228 series and, more recently, ISO/TR 12295 are useful for this specific scope.

Experiences in the application of these standards have been acquired in different parts of the world, but rarely in agriculture. This document extends the scope and methods included in existing standards to different agricultural contexts (e.g. smallholdings, industrialized farms) based on emerging application experiences. Special attention is devoted to rendering this document accessible also to non-experts. Reference is made to easily applicable, non-commercial online tools (simple tools in spreadsheets) that may be useful for the purposes of this document, making possible the application of the criteria provided here and therefore the real numerical estimate of the biomechanical overload risks.

The ISO 11228 series, ISO 11226 and ISO/TR 12295 establish ergonomic recommendations for different manual handling tasks, repetitive movements and working postures. All their parts apply to occupational and non-occupational activities. The standards provide information for designers, employers, employees and others involved in work, job and product design, such as occupational health and safety professionals.

ISO 11228 series consists of the following parts, under the general title *Ergonomics — Manual handling*:

— Part 1: Lifting and carrying;

— Part 2: Pushing and pulling;

— Part 3: Handling of low loads at high frequency.

ISO 11226 provides recommended limits for static working postures with no or minimal external force exertion, while taking into account body angles and duration.

ISO/TR 12295 serves as an application guide of the ISO 11228 series and ISO 11226. It offers a simple risk assessment methodology for small and medium enterprises and for non-professional active.

This document is intended to be used alongside ISO/TR 12295, ISO 11226 and the ISO 11228 series in the agricultural sector, where the risk from biomechanical work overload from repetitive movements, from manual handling of loads, from towing and pushing carts and awkward postures is universally present.

In addition to having deeply used the standards previously mentioned, an extensive review of the literature on methods for risk assessment of biomechanical overload applied in the agricultural setting for the prevention of musculoskeletal disorders (MSDs) has been conducted, of which the most salient data are reported.

Regarding crop production (not cattle), the assessment of biomechanical exposures at work results in 800 studies where 58 studies were selected on the basis of title and abstract. Only studies regarding crop production and reporting on risk assessment of biomechanical exposures at work were included in the analysis.

The design of the selected studies was mostly cross-sectional (70 %) and Asia was the world region from where the majority of the studies came (41 %). In addition, 10 studies were carried out in South America, 13 in North America (Canada and the USA), 10 in Europe and two in Africa. Most of the selected studies were field studies (68 %); only 8 % were carried out in a laboratory and seven studies were classified as surveys.

Regarding the applied methods, 14 studies used direct measurements (e.g. electromyography, accelerometer) and 12 studies used different types of questionnaires (self-compiled or filled in by an Ergonomist).

Six studies used the RULA (Rapid Upper Limb Assessment)[45] method.

OWAS (Ovako Working Posture Analysing System)[42] was used as a risk assessment method in five studies.

The OCRA (Occupational Repetitive Actions[21],[22]) checklist, the REBA (Rapid Entire Body Assessment)[39] method and the QEC (Quick Exposure Check)[29] method were used in nine studies (three studies).

Most of the applied methods are observational and attention is drawn to the problems related to their reliability, especially when the movements are fast.

These studies represent a summary of the papers published in the last decade in the agriculture sector. The available research has shown a lack of high-quality studies (generally using statistical “prospective” studies) to evaluate the dose-response relationship between the level of biomechanical exposure at work and the outcome (MSDs). It is necessary to consider in fact that, given the lack of results of clinical studies in agriculture (due to the widespread difficulty in subjecting workers to health surveillance), occupational exposure limits connected with the probability of generating MSDs in the agricultural setting are not available.

The OCRA checklist method, in its multi-day cycle risk assessment version,[22] is currently the only risk assessment method available in literature capable of offering criteria and application experiences to address multitask analysis (supported by a specific simple tool in the form of free download spreadsheets for final risk calculation).

ISO/TR 12295 had already adopted this multitask method of exposure analysis.

Clinical evaluation of exposed workers, conducted in multitask studies in agriculture with the OCRA method and with other methods, are still limited to few longitudinal studies due to great difficulty in having case studies subjected to health control, as there are rarely fixed-term workers, but more often seasonal workers, with high turnover, without regular work contracts and underpaid. For this reason, the prospective studies are difficult and very rarely can be concluded.

After all, the development of a method capable of predicting the appearance of pathologies (real risk assessment method) can be conquered only after years of use and improvement. The development of a new TR which, offering evaluation solutions for biomechanical overload study in agriculture, can stimulate many more valid epidemiological studies in the future, is therefore desirable. The concept of doing nothing, while waiting for sufficient and perfect published methods, means not doing prevention.

The NIOSH itself, due to the formula for calculating the lifting index (LI), changed the maximum limit value of its first formula several times over the years, through years of application experience. Recently the NIOSH added the formula for calculating the variable lifting index (VLI) for the evaluation of manual lifting tasks of complex loads, with many different weights and geometries[20],[63]. The gained experience in this type of analysis was introduced in ISO/TR 12295 and ISO 11228-1.

For the study of working postures it is important to point out the new TACOS (Timing Assessment Computerized Strategy for posture)[24] strategy, which adds to all the experience gained from the RULA and REBA methods and from ISO 11226, a more adequate timing assessment (therefore not only qualitative studies of work postures, but also studies of their real duration).

The mathematical criterion for the extension of the calculation of any risk factors for the study of biomechanical overload, not only for the working day cycle but also for cycles different in duration (e.g. annual cultivation cycles) was also discussed within a specifically activated writing group of experts for the preparation of this document. The transition is indispensable for the extension of the evaluation models already present in the specific International Standards (all used in this document) to the risk evaluation in multitask exposition with annual turnover needed for risk studies in agriculture (see Annex B).

Any other risk assessment methods that include a multitask analysis procedure can adopt the criteria here proposed, extending multitask annual exposure risk study, for instance to:

— repetitive movements (e.g. strain index, method present in ISO 11228-3);

— manual handling of loads (NIOSH formula in ISO 11228-1).

Ergonomics — Application of ISO 11226, the ISO 11228 series and ISO/TR 12295 in the agricultural sector

1 Scope

This document is intended to be used alongside ISO/TR 12295, ISO 11226 and the ISO 11228 series in the agricultural sector. This document gives information on how existing standards can be used in a global sector such as agriculture where, albeit with different characteristics, biomechanical overload is a relevant aspect, WMSDs are common and specific preventive actions are needed.

The proposed project aims to:

1) define the user(s) and fields for its application (including non-experts in ergonomics);

2) provide examples of procedures for hazard identification, risk estimation or evaluation and risk reduction in different agricultural settings, through:

   — more synthetic procedural schemes (main test);

   — more analytical explanations of the procedures, through mathematical models and application examples, also with the use of specific free simple tools, in:

      — Annex A (pre-mapping with ERGOCHECK);

      — Annex B (evaluation of Multitask risk of biomechanical overload on typical agricultural macro-cycles, considering upper limbs repetitive movements, manual lifting and carrying, pushing-pulling);

      — Annex C (study of awkward postures with criteria derived from the actual standards and scientific literature as TACOS method).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 General outline of work processes in an annual multi-task analysis in agriculture

4.1 General structure of a multi-task analysis

Specifically, this document provides additional information to aid the user in the selection and use of the appropriate standards. Depending upon whether specific risks are present, it is intended to help the user to decide which standards to apply. It will include three levels of approach (Figure 1):

— First level: the "participatory approach" for pre-mapping of danger and discomfort provides all users, particularly those who are not experts in ergonomics, with criteria and procedures to identify situations in which they may apply the ISO 11228 series, ISO 11226 and ISO/TR 12295 in different agricultural settings (key-enter and key-questions level). Only in the early analytical stage is the opportunity offered to map, even if only using subjective data obtained by interviewing the workers (through the identification of groups of workers, homogeneous for exposure to occupational risks), all the occupational hazards and not just the risk of biomechanical overload.

— Second level: provides a "quick assessment method" (according to the criteria provided in ISO/TR 12295) for easily recognizing activities that are "definitely acceptable or definitely critical". If an activity is "neither definitely acceptable nor definitely critical", it is necessary to complete a detailed risk-assessment as set out in the standards, continuing with the necessary subsequent preventive actions.

— Third level: refer to detailed methods for risk assessment set out in the relevant standards when the quick assessment method shows that the activity risk falls between the two exposure conditions (definitely acceptable or definitely critical).

The above approaches and scopes are illustrated in the flowchart in Figure 1 and are described in the main text of ISO/TR 12295.

At first the user is required to answer a short series of practical questions present in the first and second level. It is emphasized that the quick-assessment method is best implemented using a participatory approach involving workers in the enterprise (homogeneous groups of workers).

This involvement is deemed to be essential for effectively setting priorities for dealing with the different hazard and risk conditions and, where necessary, identifying effective risk reduction measures.

In agriculture evaluation it can be possible to limit the study to the first and second levels, obtaining sufficient data about occupational risk priorities.

The analytical risk assessment approach (third level) provides all users, especially those experienced in ergonomics, or familiar with the ISO 11228 series, with details and criteria for applying the risk assessment methods proposed in the original standards also to agriculture.

This analytical risk assessment approach is fully consistent with the methods proposed in the standards and does not introduce any changes in the criteria (mathematical model) for risk calculations, defined in the existing standards (as well expressed in ISO/TR 12295) but only adapts the proposed methodology to the risk assessment in agriculture.

The proposed additional analyses aim to facilitate the use of the actual standards, making it possible to extend them to risk assessment in agriculture (Annexes A, B and C).

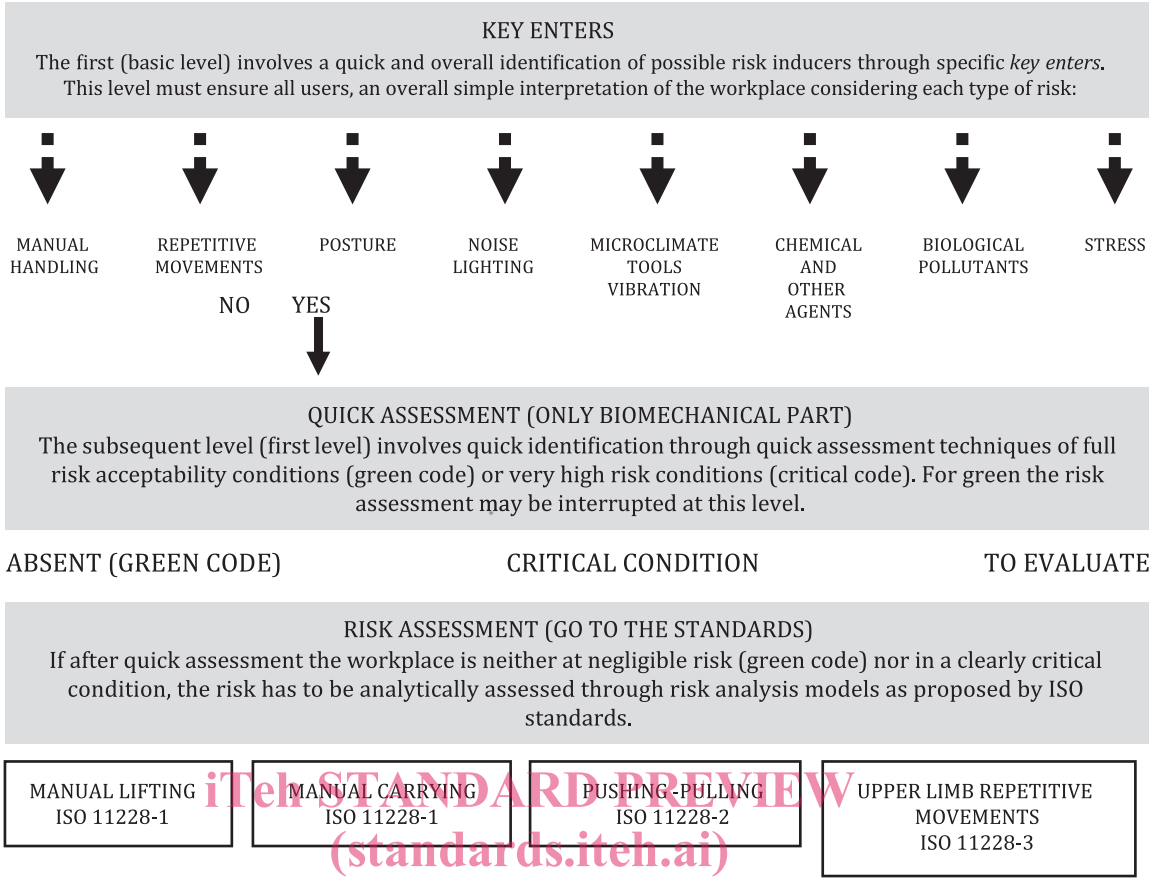

Figure 1 — Different risk assessment levels according to ISO/TR 12295 for biomechanical overload estimation

4.2 Study of tasks distribution over the year and search for groups of workers who are homogeneous in terms of risk exposure

4.2.1 General

In a setting such as agriculture, before starting a risk analysis, it is necessary to define a set of procedures and criteria for estimating risk in complex situations where workers perform multiple tasks, variously distributed in qualitative and quantitative terms over the year (annual cycle).

The general risk evaluation process entails a certain number of steps, beginning with:

a) identification of the macrocycle of the many different tasks;

b) analysis of farming tasks to identify tasks performed within the period and obtain a qualitative definition of the work during each month of the year;

c) identification of one or more homogeneous groups.

4.2.2 Macrocycle duration

Task rotation is when a worker alternates between two or more tasks during a certain period of time; this situation occurs quite often in modern work organizations and, if properly designed, can represent one of the most effective strategies for reducing the risk of biomechanical overload.

In special situations, such as in agriculture, where the worker has to perform a large number of tasks and the tasks are distributed “asymmetrically” over the shift, risk assessments can become extremely

complex. This is why it is necessary to carry out a thorough preliminary study of how the work is organized. At any rate, the risk analysis process involves different steps, listed further on.

The first step consists in defining the time required to complete the task rotation schedule; this is the macro-cycle time, which may be daily, weekly, monthly or yearly.

The types of macrocycles durations are infinite, but if there are no simplification criteria that allow us to estimate the risk, every risk assessment stops and nobody does anything (the excuse being that the mission is impossible).

The modal macro-cycle periods appear to be, at least in the sectors of agriculture, building construction and services, accurately representative of job cycles. In agriculture, task rotations are typically annual, but one can use annual cycles even when multiple cycles of fewer months in each year are repeated identically (e.g. multiple harvests per year of the same product). In the construction sector there is generally a yearly cycle for large construction sites, but a monthly cycle (modal) is more frequent in smaller-scale constructions and civil renovation projects. In other sectors (e.g. logistics for retail chains, cleaning services, food preparation facilities), the most common rotation scenario is monthly, while in yet other situations (e.g. supermarkets) tasks can be rotated on a weekly or, occasionally, a monthly basis.

In summary, some practical suggestions are provided here for using the predefined macro-cycle (weekly, monthly, yearly), thus certainly simplifying subsequent evaluations:

— If several identical sub-macro-cycles are repeated over the year, use the annual macro-cycle.

— If several identical sub-macro-cycles (e.g. week, fortnight) are repeated within the month and if the following months are similarly repeated, use the monthly macro-cycle.

Whichever macro-cycle duration is chosen, the criteria and procedures for dealing with the biomechanical overload risk analysis are the same. Given the extreme activity variability, the recommendation is, however, to identify and evaluate representative modal scenarios.

4.2.3 Phases and tasks identification

It is not simple to identify farming tasks, which may be very numerous and performed by different workers or groups of workers. At the outset, therefore, it is necessary to:

a) identify the specific cultivation or crop;

a) break down the crop-growing activities into phases; all relevant tasks must be identified inside each phase.

The same activity can be carried out in several different ways; each operating method is intended to be viewed as a separate task and listed accordingly (e.g. pruning with manual tool or pruning with pneumatic tool).

It is important to note that all the tasks performed at the farm over the year have to be evidenced, including preparing the soil, applying fertilizers and disinfectants and other seemingly ancillary activities, regardless of who performs them.

As it is so inherently difficult to identify phases and tasks in the crop growing or cultivation process,[21],[22],[25] a kind of universal cultivation system has been developed that will enable even beginners to conduct a preliminary organizational analysis in an agricultural setting.

It consists of phases (soil preparation, treatment, disinfection and fertilization, planting, intermediate processes, harvesting) that include a certain number of typical tasks broken down by type, technique and tools (Table 1).

Table 1 — Principal tasks characterizing a generic cultivation: the universal cultivation system

Preparation and treatment of soil, mechanical weeding	with tractor
	with animals
	with manual tools
	manual carrying (weight up to max. 3 kg)
	manual carrying (weight 3 kg)
	with manual tool and pulling or pushing
	other activities, without tools, with repetitive movements of the upper limbs (without lifting up to max. 3 kg)
	other activities, without tools, with repetitive movements of the upper limbs (with lifting up to max. 3 kg)
Disinfection, disinfestation, fertilizing, chemical weeding	with tractor
	manual with machinery
	manual with tools
	with manual tools and pulling or pushing
	other activities, without tools, with repetitive movements of the upper limbs (without lifting up to max. 3 kg)
	other activities, without tools, with repetitive movements of the upper limbs (with lifting up to max. 3 kg)
Planting	automatic with tractor
	semi-automatic with tools or machinery
	manual with manual tool (product weight up to max. 3 kg)
	manual without tools (product weight up to max. 3 kg)
	manual with manual tool (product weight over 3 kg)
	manual without tools (product weight over 3 kg)
	manual carrying (product weight up to max. 3 kg)
	manual carrying (product weight over 3 kg)
	with manual tool and pulling or pushing
	other activities, without tools, with repetitive movements of the upper limbs (without lifting up to max. 3 kg)
Intermediate farm work (e.g. pruning, binding, thinning)	pruning with manual tools
	pruning with pneumatic or electric tools
	pruning with chainsaws
	manual pruning without tools
	manual carrying (weight up to max. 3 kg)
	manual carrying (weight 3 kg)
	with manual tool and pulling or pushing
	other activities, without tools, with repetitive movements of the upper limbs (without lifting up to max. 3 kg)
	other activities, without tools, with repetitive movements of the upper limbs (with lifting up to max. 3 kg)

Table 1 *(continued)*

Harvesting of crops	automatic with tractor
	semi-automatic with tools or machinery
	manual with manual tool
	manual with pneumatic or electric tools
	manual without tools
	manual carrying (weight up to max. 3 kg)
	manual carrying (weight 3 kg)
	with manual tool and pulling or pushing
	other activities, without tools, with repetitive movements of the upper limbs (without lifting up to max. 3 kg)
	other activities, without tools, with repetitive movements of the upper limbs (with lifting up to max. 3 kg)

4.2.4 Identification of the different homogeneous groups

The next step is to assign tasks to an individual worker or group of workers exposed to the same risk, to identify homogeneous groups. Since the focus of the analysis is the exposure of workers to a set of conditions determined by the tasks they are assigned to perform, it is first necessary to identify which homogeneous group of workers are present that need to be examined.

The homogeneous group of workers for risk exposure (as groups of workers homogeneous for working risks are being defined, not groups of people homogeneous for other factors, such as weight, age, culture or gender) is the group of workers that performs the same tasks, in the same workplace and with similar durations (or time patterns) during the selected period (macro-cycle).

Note that a homogeneous group may sometimes be made up of just one person, if no other workers perform the same tasks qualitatively and quantitatively.

Moreover, if two groups of workers perform the same tasks in the same workplaces but with different durations or time patterns (e.g. one group works full-time and the other works part-time) the two groups must be analysed separately.

For instance, typically (as presented in Table 2), a single group of workers may be assigned the job of actually growing a crop (tasks may include pruning and harvesting) (homogeneous group 1), while other workers prepare and disinfect the soil, apply fertilizers and so on (homogeneous group 2), as presented in Table 3.

Homogeneous groups of seasonal workers can also be present, who are called to work only in the harvesting phase (Table 4).

The assignment of the tasks to a homogeneous group (or individual worker) even just from the qualitative standpoint (or semiquantitative as here), is not difficult but it is absolutely essential before conducting the first levels of risk evaluation (key questions and quick assessment level).

To determine the real risk exposure (risk assessment level) it is necessary to study a quantitative description of all active tasks.

Only after this organizational analysis, can the different risk levels be assessed in terms of repetitive movements, manual load handling, awkward postures and pushing-pulling.

Table 2 — Example of description of tasks (pruning and harvesting) performed monthly by homogeneous group 1

Tasks	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Plowing (tractor)												
Installing irrigation system												

Table 2 *(continued)*

Tasks	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Planting (manual)											40 %	10 %
Planting (mechanical)											20 %	90 %
Pruning large branches with chainsaws												
Pruning with manual shears										50 %	5 %	
MMH of large branches										40 %	30 %	
Pruning with manual shears		70 %	70 %	60 %	60 %	60 %						
MMH of small branches		20 %	20 %	30 %	30 %	30 %						
Manual harvesting on ground							45 %	45 %	45 %			
Manual harvesting on ladder							35 %	35 %	35 %			
MMH of ladder							10 %	10 %	10 %			
Preparing machine to apply fertilizer												
Driving tractor												
Composting (manual)												
Disinfection (manual)												
Disinfection (tractor)												
Push/pull trolley-large branches		5 %	5 %	5 %	5 %	5 %				5 %	5 %	
Push/pull trolley-small branches		5 %	5 %	5 %	5 %	5 %				5 %		
Push/pull trolley-fruit boxes							10 %	10 %	10 %			
	0	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %

Table 3 — Example of description of tasks (workers prepare and disinfect the soil, apply fertilizers) performed monthly by homogeneous group

Task	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Plowing (tractor)	40 %	20 %	20 %	20 %	40 %	30 %	30 %	30 %		100 %	20 %	20 %
Installing irrigation system	20 %											
Planting (manual)												
Planting (mechanical)											20 %	20 %
Pruning large branches with chainsaws												
Pruning with manual shears												
MMH of large branches												
Pruning with manual shears												
MMH of small branches												
Manual harvesting on ground												
Manual harvesting on ladder												
MMH of ladder						70 %	70 %	70 %				
Preparing machine to apply fertilizer		10 %	10 %	10 %							20 %	20 %
Driving tractor		40 %	40 %	40 %							20 %	20 %
Composting (manual)		10 %	10 %	10 %							20 %	20 %
Disinfection (manual)	20 %	10 %	10 %	10 %	30 %							
Disinfection (tractor)	20 %	10 %	10 %	10 %	30 %							
	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	0	100 %	100 %	100 %

Table 4 — Example of description of tasks (harvesting) performed by a seasonal homogeneous group

Tasks	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Plowing (tractor)												