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MECHANIZATION AND INPUT REDUCTION IN PROCESSING TOMATO
CROPPING : AGRONOMIC ASPECTS; BUILDING AND TESTING OF
APPROPRIATE TECHNICAL WAYS OF MANAGEMENT

Y. DUMAS

Institut National de la Recherche Agronomique
Station d'Agronomie
B.P. 91, 84140 MONTFAVET
FRANCE

Abstract

This study deals with the agronomic feasibility and the results of mechanized ways of management for processing tomato which were likely to meet the following main objectives : a) field state suitable to mechanical harvest, b) satisfying yield (60 to 80 t.ha⁻¹), c) input reduction. The agronomic constraints deriving from them and pluridisciplinary scientific results were used as a base of reasoning and then of building technical management schedules. Most of these constraints have been considered and integrated into ways of management of processing tomato crops in large plots during 3 years (1985-86-87) on a clay alluvial soil. Management decisions were taken according to periodical simple diagnoses based on observing, counting or measuring. The main objectives were satisfied namely : 1) a total mechanization (except one or two partial hand weeding), with a reduced number of operations, 2) reduced fertilization : for P, in a poor soil, half of the current supplies and for N about one quarter, 3) reduced plant protection, including biological means, 4) good field fitness to mechanical harvest, 5) annual yields respectively : 78, 75 and 50 t.ha⁻¹. The results show that it is possible to produce otherwise and cheaper while reducing resources wasting and improving environment safety.

1. Introduction

In many countries growing processing tomatoes hand labour becomes more and more expensive. Silviero (1986) considered that it could represent 70 to 75 % of production cost with 60 % concerning hand harvest. Producers try to reduce it and turn more and more towards the mechanization of a maximum of cultural operations including harvest with the will to simplify tomato cropping. In the mediterranean area, this involves progressive adjustments of cropping systems. For mechanization development generally leads to important modifications in the concerned crops management (Sims, 1985). A successful once-over harvest and above all a mechanical one lead the producer to reconsider all the technical operations and their timing (Di Candilo et al.,

1987). An effort is needed for the creation or the adaptation of machines (Nicolas et al., 1987).

In the South of France, one of the possibilities for producers to keep processing tomato competitive lies in mechanizing but also in reducing production costs without much penalizing yield level. This implies that we produce in a better way through a better use of production factors.

So the present study deals with the agronomic feasibility and results of mechanized ways of management which were likely to meet the following main objectives :

a) field state suitable to mechanical harvest at the crop cycle end,

b) satisfying yield (60 to 80 t ha⁻¹),

c) inputs reduction (energy, fertilizers, pesticides).

2. Materials and methods

Starting from previous experiments (Dumas et al., 1983) and surveys by farmers', we have built diagrams as a basis for the conception of technical ways of crop management adapted to the above objectives.

Figure 1 briefly presents the main agronomic constraints from point a). It shows that mechanical harvest choice completely structures the types of field operations which are to follow each other. These constraints lead to problems of technical choices or tactics. The weight of mechanical harvest greatly influences the choice of cultivars, which must combine many suitable characteristics (Stevens, 1979, Galban et al., 1978, Ruiz Altisent et al., 1980), but also of soil preparation, fertilization, crop timing as sowing date which influences harvesting date.

Figure 2 presents an example of constraints, above all through fertilization aspects, generated by points b) and c). This topic has induced specific studies. Phosphorus placement was studied (Dumas, 1988) in order to increase young seedlings growth rate with moderate P amounts, since P is expensive and easily becomes insoluble in many soils. Nitrogen supply was also studied (Dumas, unpublished) in field experiments which showed that : (i) supplies bigger than 100 kg N ha⁻¹ induced a new plant branching before harvest and very high nitrate residues in the soil profile after harvest (200-250 kg N ha⁻¹ for 1 m deep), (ii) apparent soil mineralisation, during tomato crop and for 1 m deep, supplied 120-150 kg nitric N ha⁻¹, (iii) without N supply tomato stand showed N stress only after the appearance of the first trusses (beginning of high growth rate and root system still small). So taking into account soil nitrates residues at emergence time, N supplies could be strongly reduced while making them available by placement.

All these points have been considered and integrated into ways of management of crops experimented on large plots (2500 m², replicated 3 or 4 times) during 3 years (1985-86-87) on an alluvial clay soil (table 1) near Avignon in the S.E. of France. Table 2 gives the main characteristics of the 3 year climate. The cultivar was Earlymech (UC82 from Petoseed). Field operations were carried out with an equipment mostly commonly used by farmers of the region.

Tomatoes were direct-seeded in May, after wheat. Water supply was performed by sprinkler irrigation (8-9 mm h⁻¹) according to a balance between climatic demand, rainfall and soil water reserve on the rooting depth. Potential evapotranspiration was daily calculated by Penman formula and rooting depth was estimated from previous studies, i.e. 15 cm at 1st truss time, then 1.5 cm d⁻¹ increase till end of flowering, then increase of 1.0 cm d⁻¹ diminishing to 0 near harvest. Table 3 gives the successive values used for the crop coefficient K_c (ratio of crop maximum evapotranspiration to potential evapotranspiration). Water supply was decided when usable water reserve had decreased down to 40% of its maximum actual value. The last irrigation took place at the beginning of ripening time. Soil profile nitrate content was measured by soil sampling and ionometry at emergence time. Plant protection was decided as follows : for diseases, use of local official warnings and weekly field observation; for insects, during risky periods, weekly countings of aphids numbers with high-pressure spraying decision when 10 aphids per leaflet from young shoots for a 60 leaflets sample (Bues et al., 1985), weekly countings of *Heliothis armigera* eggs and high-pressure spray when 2 eggs observed in a 50 leaves sample (Bues et al., 1988).

3. Results

Table 4 gives an example, for 1985, of the successive operations performed on the fields. 1986 and 1987 were very similar with only one cultivator passage and small differences in plant protection : one insecticide spray (acephate against fruitworm) and two fungicides in 1986; one acephate and two *Bacillus thuringiensis* against fruitworm and two fungicide sprays in 1987; there never were any intervention against aphids. In 1986 and 1987 there were 12 irrigations with 327 mm and 359 mm respectively. The main objectives were satisfied namely :

3.1. A total mechanization except partial hand weedings

Every field operation could be mechanized, with reducing the number of interventions to save time and energy e.g. few but rather early soil tilling operations (digging machine and one or two vibrating tine cultivator passages), P placement while bed raising, N placement while mechanical weeding etc. But weed-control needed hand interven-

tions. Main weeds were : *Amaranthus retroflexus*, *Chenopodium album*, *Papaver rhoeas*, *Galium asparine*, *Convolvulus arvensis*, *Cirsium arvense*, *Polygonum convolvulus*, *Solanum nigrum*, *Lepidium draba*, *Portulaca oleracea*. Partial hand weeding was necessary in 1985 and 1986 on the row just after mechanical weeding, and on some areas at ripening time against *Solanum nigrum* only.

3.2. A reduced fertilization

On an average, local farmers usually broadcast 150 kg N, 110 kg P and 250 kg K ha⁻¹. Here on a soil very poor in phosphorus, half P was supplied, one quarter N and no K; For each year, soil residual nitric N content was comprised between 12 and 25 ppm in the upper layer 0-20 cm corresponding to 30 to 60 kg N ha⁻¹ after emergence. So in our conditions 15 to 20 ppm nitric N seemed sufficient for plant supply until the appearance of the first trusses. At that stage, we measured 80 to 100 kg nitric N ha⁻¹ on 40 cm deep and 150 to 200 kg on 1 m deep.

3.3. Light plant protection

Due to countings and observations, few pesticides interventions were performed. As a comparison, official warnings advised 8-10 fungicides in 1985 and 4 in 1986 and 7-8 insecticides in 1985 and 4 in 1986. High aphids populations were accepted on young plants kept vigorous owing to high growth rate (P availability). *Bacillus thuringiensis* was used as often as possible against fruitworm according to larvae development stage.

3.4. A good crop fitness to mechanical harvest

Red fruit percentage generally was over 90%. Vegetation was half dried, soil structure was thin and present weeds without very tall individuals did not disturb harvest. Fruit losses varied from 1 to 5%.

3.5. Yields were respectively 78, 75 and 50 t ha⁻¹ in 1985-86-87. 1987 worse yield could be explained by a non favourable climate, a seeding error (350 000 plants ha⁻¹ instead of 120 000-150 000, without thinning possibility) and a deficient irrigating system (water excess). Nevertheless 1987 yield was not so bad on a local basis. Average fruit weight was about 50-60 g for 1985 and 1986 and 40-45 g for 1987. Fruit technological characteristics were good : Ph 4.1 to 4.3, refract. index 5.0 to 6.0, dry solid content 6.0 to 6.5.

4. Discussion

These experiments, carried out in technical conditions very similar to farmers' and sometimes with harder human or time constraints, showed at evidence that input sparing is possible and can lead to satisfying results.

Without very much sophisticated equipment it was possi-

ble to perform simultaneous field operations, which is interesting for time and energy use and allow substantial cost reduction (Conea et al., 1984). The best results of input reduction were obtained for fertilization and plant protection. Fertilizer placement, with a simple equipment, considerably reduced the supplied amounts with a good result. For in 1985 and 1986, N uptake from soil reached about 200 kg ha⁻¹. However a better knowledge of nutrients dynamics in soil and plant seems necessary to provide better decision arguments. For here the decision of supplying 40 N ha⁻¹ was based on rather simple observations and an extension to other soil types has to be studied. By another way one must look after that such a management does not lead to a decrease of soil chemical fertility which has to be maintained through crop successions. For plant protection, interventions were also simplified, undoubtedly owing to well argued choices but also to climatic years rather unfavourable to mildew.

In fact it also clearly appeared that input reduction cannot be uniform for every point. For instance water requirements must be strictly satisfied during germination and emergence time (frequent irrigations needed on the present soil which is rapidly mulching on 2-3 cm deep with dry windy weather) and especially during flowering and fruit set time. In the same way various year types can induce changing number and intensity of sanitary problems. Weeds were badly controlled, and this can also be a reason of varying costs among years.

Important progress can be made in that way by producers who must give more time to observing and by researchers who must provide producers with suitable decision indicators rather easy to observe in order to ameliorate diagnosis and increase factors efficiency. Nevertheless these results show that it is possible to produce otherwise and cheaper by a reasoned way, while reducing at the same time the wasting of various resources and improving environment safety and products quality.

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Table 1. Main soil characteristics

Granulometry (�/��)	
<0.002 mm	530
0.002 to 0.020 mm	320
0.020 to 0.050 mm	40
0.050 to 0.200 mm	75
0.200 to 2.000 mm	35
Total CO ₃ Ca (�/��)	250
Organic matter (�/��)	20
Total nitrogen (�/��)	1.2
P (extraction by ammonium oxalate) (�/��)	0.044
Exchange capacity , Metson meth. (me 100g ⁻¹)	25
K-ions exch. by ammon.acet. (me 100g ⁻¹)	1.2
Mg-ions exch. by ammon.acet. (me 100g ⁻¹)	3

Table 2. Climate characteristics for the cropping periods

		1985			1986			1987		
		T	PET	P	T	PET	P	T	PET	P
May	1st dec	12.9	33	38	16.2	35	16	13.2	40	5
	2nd dec	13.9	28	66	19.1	41	0	13.7	38	45
	3rd dec	18.6	49	0	19.2	59	1	17.1	58	0
June	1st dec	19.3	43	3	17.0	54	0	18.8	46	10
	2nd dec	18.6	48	11	20.1	50	90	18.3	48	21
	3rd dec	19.8	52	15	23.6	54	0	22.0	59	11
July	1st dec	24.7	59	0	23.6	62	2	25.3	55	34
	2nd dec	24.0	54	0	22.8	69	0	22.1	43	56
	3rd dec	23.7	59	0	23.8	57	0	21.7	63	1
Aug	1st dec	21.1	49	62	25.1	53	0	22.3	54	1
	2nd dec	23.1	50	0	23.5	47	7	26.2	54	0
	3rd dec	20.9	43	55	19.9	44	128	21.2	38	112
Sept	1st dec	21.8	48	0	19.6	39	0	21.9	37	2
	2nd dec	20.1	32	0	21.0	28	53	22.8	28	0
	3rd dec	21.3	24	0	18.2	23	37	19.0	25	51

T : mean air temperature for one decade (°C)

PET : potential evapotranspiration (Penman formula), sum for one decade (mm)

P : rainfall, sum for one decade (mm)

Table 3. Crop coefficient Kc used for crop maximum evapotranspiration (MET) calculation from potential evapotranspiration (PET)

Plant stage	emerg.	1-2 trus. /plant	3-4 tr. /pl.	1st flow.	1 tr. with fl./pl.
Kc=MET/PET	0.3	0.4	0.5	0.6	0.8
duration (days)		5	5	4	4
Plant stage	1st fruits	1 tr. with fr./pl.	2 tr. with fr./pl. half fl9	half fruit set	end of flow9
Kc=MET/PET	1.0	1.05	1.1	1.15	1.20
duration (days)	4	4	6	8	

Table 4. Technical operations performed in 1985

Digging machine on 20 cm, 29 Oct 1984
 40 P ha⁻¹ (triple superphosphate) broadcasted, 2 Apr 1985
 Diquat, 3 Apr
 Vibrating tine cultivator, 23 Apr
 Beds raising and placement of 20 P ha⁻¹ under rows, 23 Apr
 Direct-seeding and microgranulated insecticide placement
 on seeds, 30 Apr
 Difenamid (3200 g ha⁻¹) + metribuzin (160 g ha⁻¹), 6 May
 Irrigation : 22 May: 9 mm - 24 May: 10 mm - 28 May: 20 mm
 30 May: 10 mm - 5 Jun: 6 mm - 21 Jun: 10 mm - 3 Jul:
 38 mm - 10 Jul: 58 mm - 16 Jul: 62 mm - 25 Jul: 64 mm
 3 Aug : 80 mm .Total water supply : 367 mm
 At 2-3 trusses per plant time, mechanical weeding with
 placement of 40 N ha⁻¹ (ammonium nitrate) on rows,
 partial hand weeding on rows, 17 Jun
 Metribuzin (500 g ha⁻¹) at half flowering time, 12 Jul
 Partial hand weeding (*Solanum nigrum*), 5 Aug
Bacillus thuringiensis spray, 22 Jul
Bacillus thuringiensis spray, 29 Jul
 Fongicide (chlorothalonil), 31 Jul
 Ethephon spray at 50% red + pink fruit time, 21 Aug
 Mechanical harvest, 11 Sep, yield : 78 t ha⁻¹

Figure 1. Main agronomic constraints from mechanical harvest

Figure 2. Elements for reasoning fertilization management in a context of inputs reduction and mechanized processing tomato cropping