CONSIDERATIONS ON HEMP STALK HARVESTING USING SPECIALIZED EQUIPMENT
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CONSIDERAŢII PRIVIND RECOLTAREA TULPINII DE CÂNEPĂ UTILIZÂND UN ECHIPAMENT SPECIALIZAT

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ABSTRACT
Within the current hemp cultivation technologies, the use of high-performance technical equipment is required for all applied works, and following the concerns regarding diversified and efficient ways of harvesting, INMA Bucharest has created and experimented an innovative technical equipment for harvesting and tying the stalks into sheaves. In order to demonstrate the efficiency of this equipment, the paper presents the experimental results obtained by INMA Bucharest regarding hourly fuel consumption and fuel consumption per hectare. These energetic indices are important in the evaluation of expenses per surface unit, constituting the basis of the economic efficiency evaluation. At the same time, at ARDS Secuieni, in 2021, research was carried out on the influence of the cuttings application and different sowing norms on the agro-productive capacity of the Ratza monoecious hemp variety for stalks and fibre. The obtained results constitute premises in order to optimize some technological links of cultivation at hemp for stalks and fibre, but they also confirmed the fact that fuel consumption per hectare recorded at hemp stalks harvesting was influenced both by the technical characteristics of the equipment used and by the characteristics of the experimented crop.

REZUMAT
În cadrul tehnologiilor actuale de cultivare a cânepei se impune utilizarea unor echipamente tehnice performante pentru toate lucrările aplicate, iar în urma preocupărilor privind modalități diversificate și eficiente de recoltare, INMA București a realizat și experimentat un echipament tehnic inovativ pentru recoltarea și legarea tulpinilor în snopi. În vederea demonstrării eficienței acestui echipament, în cadrul lucrării sunt prezentate rezultatele experimentale obținute de INMA București privind consumul de combustibil orar şi consumul de combustibil la hectar. Acești indici energetici sunt importanți în evaluarea cheltuielilor la unitatea de suprafață, constituind baza evaluării eficienței economice. Concomitent, la SCDA Secuieni, în anul 2021, au fost derulate cercetări privind influența aplicării retezărilor și a diferitelor norme de semănat asupra capacității agroproductive la soiul de cânepă monoică pentru tulpini și fibră Ratza. Rezultatele obținute constituie premise în vederea optimizării unor verigi tehnologice de cultivare la cânepa pentru tulpini și fibră, dar au confirmat și faptul că consumul de combustibil la hectar înregistrat la recoltarea tulpinilor de cânepă a fost influențat atât de caracteristicile tehnice ale utilajului folosit, cât și de caracteristicile culturii experimentate.

INTRODUCTION
In recent years, there has been considerable development in the industrial hemp industry, contributing to the development of the national economy and thus of the world economy. In our country, after 1989, the cultivation of industrial hemp (*Cannabis sativa* L.) experienced a spectacular decline caused, in large part, by the impact of the transition period on the industrial sector, especially on the sector dedicated to stems processing, by the restructuring of the agricultural sector, but also because of the legislation, which included this culture in the category of those from which narcotic substances are extracted. Currently, industrial hemp is no longer a crop prohibited or restricted by law, only that such a plantation must be authorized and monitored by various state institutions, depending on the country in which it is grown. The industrial hemp sector has transformed from a fibre-based processing sector into a more complex industry, including the healthcare, textile, automotive, etc. sectors (*Ceyhan, V. et al., 2022*).

Beyond the impediment related to authorization and monitoring, hemp cultivation brings more than profitable profits to those who invest in it. It is cultivated for its relatively high natural fibre content and for its seeds rich in siccative oil. Among the textile plants of the temperate climate, hemp provides the highest amount of fibre per hectare (2.2 - 5.5 t/ha) (*Trotuş, E. et al., 2020)*. Hemp fibres are durable, resistant, longer than the flax ones and are used in the manufacture of a wide range of textiles, and impregnated with various plastics, they can be used in various fields of the technical industry (*Matthew, R.L., 2020; Trotuş, E. et al., 2020; Stroescu, Ghe. et al., 2021*). Shorter fibres resulting from processing are a very good fuel, but are also used in the manufacture of cellulose, particle board, insulation boards, and which by treatment improve the properties of composites reinforced with such fibres (*Zane, Z. et al., 2020)*.

The cultivation of hemp for seed production is due to the multiple applications in the technical, food, cosmetics and fodder fields. In the literature (*Grégoire, M. et al., 2020*) it is highlighted that it is important that the whole hemp plant can be valued, being known for its multifunctionality.

Combined harvesting systems capable of simultaneously harvesting seeds and stalks have been designed for hemp harvesting, as specified by the authors (*Gusovius, H.-J. et al., 2016*).

Natural fibres have been threatened by the growth of artificial fibre alternatives, so natural fibre industries must remain competitive, must continue technological progress through mechanization, the use of synthetic or natural fertilizers, plant protection chemicals and genetic engineering tools (*Townsend, T. 2020)*.

The production of stalks, respectively of fibre per surface unit is influenced, among other things, by the cultivation technology applied and the genotype used. Agricultural Research and Development Station Secuieni created and homologated monoecious hemp genotypes for stalks and fibre, Dacia-Secuieni and Ratza, and studied different technological links to increase the agro-productive capacity of its genotypes, while maintaining the THC content within legal limits (*Popa, L.D. et al., 2022*).

At INMA Bucharest, following the concerns for the diversification of hemp harvesting equipment, innovative technical equipment for stalks harvesting and sheaf-binding has been designed, developed and tested.

Considering the above mentioned, in the present work both the combined influence between the application of cutting and the seed norm used, on the agro-productive capacity of a monoecious hemp genotype, as well as the hourly fuel consumption, respectively the consumption per unit, were experimented. The results obtained will allow the establishment of some optimal technological links for cultivation, while the knowledge of the energy indices will be useful for the evaluation of expenses per hectare, in order to draw up the expense-income balance, which is the basis of the assessment of economic efficiency.

MATERIALS AND METHODS

The biological material was represented by Ratza monoecious hemp genotype for fibre. This is an energetic variety, homologated in 2016, created following the appearance of a natural mutation in the Alice genotype, followed by isolation and repeated individual selection. The production potential of the variety is 700-800 kg/ha seed and 20.0-25.0 t/ha energetic stalks (*Trotuş, E. et al., 2020*).

In 2021, a monoecious hemp culture for fibre was established in the experimental field of the Agricultural Research and Development Station Secuieni, Neamț, according to (fig. 1), where the combined influence of applied cutting and seed norm on stalk production was studied. The experimental field was of the subdivided plots type, corresponding to the studied factors: factor A = type of cutting, with two graduations (a_1 = NT, uncut, a_2 = T1, cut once); factor B = seed norm, with three graduations (b_1 = 20 kg/ha, b_2 = 40 kg/ha, b_3 = 60 kg/ha).

In autumn, after harvesting the preceding plant, ploughing was carried out at a depth of 25 cm. In the spring, when preparing the seedbed, a levelling was carried out with the disc harrow, followed by a pass with the combine. Taking into account the fact that the species is demanding on the content of nutrients in the soil, complex fertilizers N:P:K 16:16:16 were administered, in the amount of 300 kg/ha.

The crop was established in the last decade of April, the sowing being followed by herbicidation with Aloha, in a dose of 1.5 l/ha. During the vegetation period, specific maintenance works were carried out on the experimental plots. Within the T1 variant, the Secuieni method of cultivating monoecious hemp for seed was applied, which is the subject of the patent (*Găucă, C.*, *Patent no. 115211*). The method consists in the mechanized cutting of plants that have 5-6 nodes formed, 20-30 cm from the ground level, resulting in the development of new shoots with inflorescences, obtaining more uniform crops, but also a reduction in the height of the field (*Trotuş, E. et al., 2015; Gherasim, A., 2017*).

The cut crop will allow the harvesting of hemp for seed directly from the field, with combines for cereals, with the header raised below the point of insertion of the inflorescences, and for hemp for fibre by using technical equipment with devices for cutting and binding the stalks.

Fig. 1 - Appearance from the culture for fibre

During the course of the experiments, the evolution of the experimental field of monoecious hemp variety Ratza was followed, in the meteorological conditions of the 2020-2021 agricultural year (fig. 2 and fig. 3) and the combined impact of cutting and the seed norm used on the production of stalks.

The 2020-2021 agricultural year is characterized as hot and dry, with the average annual temperature being 9.9°C, being 1.0°C higher than the multiannual average (8.9°C).

In five calendar months, there were quite large deviations of the average monthly temperature, between +1.6°C and +3.6°C, compared to the multiannual average. The low temperatures in April and May, with large temperature alternations from day to night, but also from one day to another, were considered atypical for this period of the year, the monthly deviation being -2.0°C, respectively -0.7 °C compared to the multiannual average.

The amount of precipitation recorded between October 2020 and September 2021 was 399.8 mm, with145.5 mm less than the multiannual amount of 544.3 mm, with the agricultural year falling into the dry category.

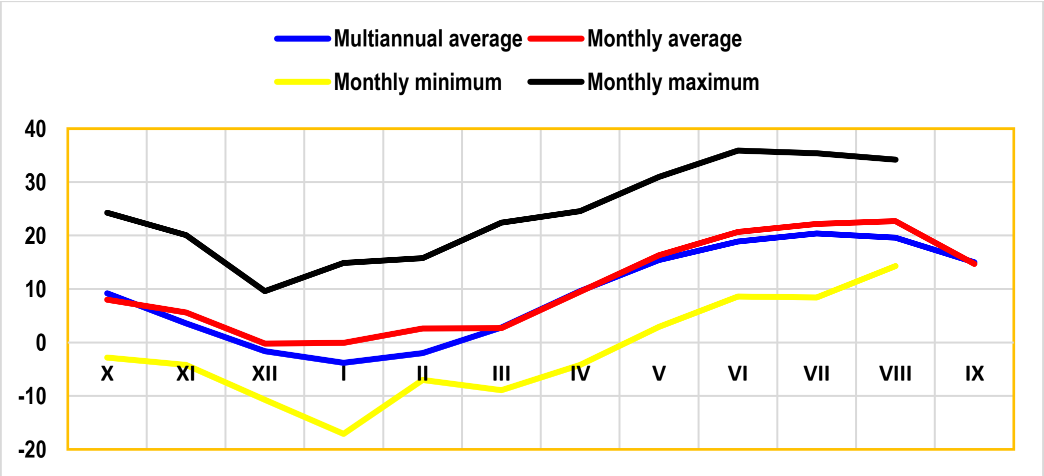

Fig. 2 - The evolution of the minimum, maximum and average temperatures recorded at ARDS Secuieni

The collection of samples from each variant was done manually, in the second decade of August, the experimental data obtained being processed statistically by methods specific to bifactorial experiences. The production increases recorded were assessed by calculating the limit differences (*Leonte and Simioniuc, 2018*).

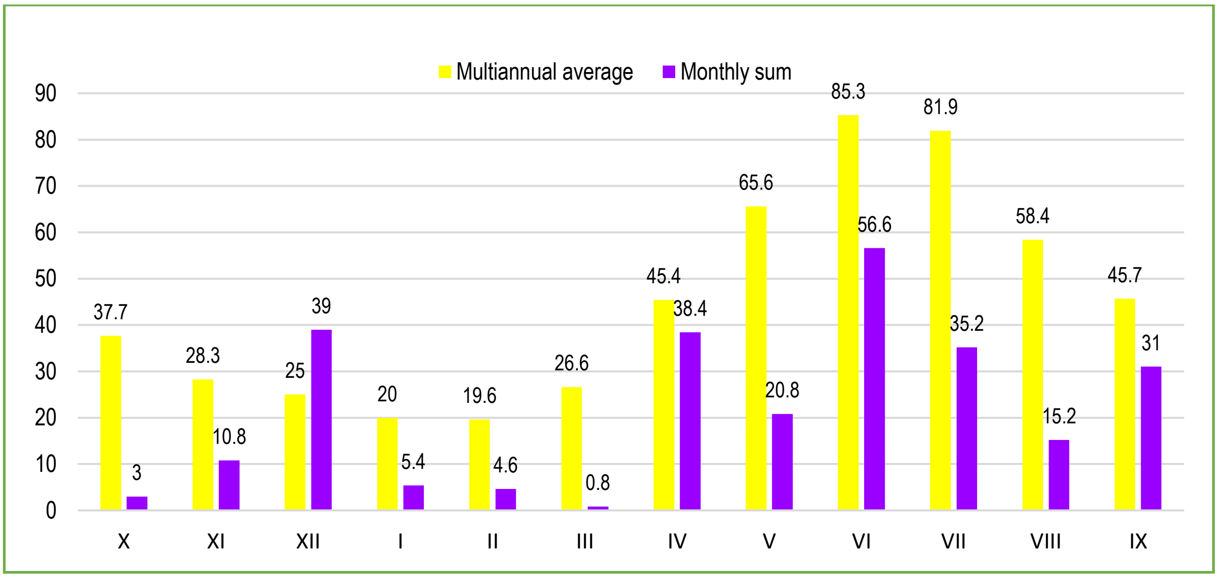

Fig. 3 - Evolution of monthly precipitation recorded at ARDS Secuieni

As a result of collaboration between A.R.D.S. Secuieni and INMA Bucharest was developed an experimental model for harvesting hemp stalks (fig. 4), which performs: stalk cutting, sheaf-binding, loading on the equipment platform and unloading on the ground, on the side of the working system.

Fig. 4 - The experimental model, SRC, for harvesting and binding the hemp stalks

Some of the results of the experiments on the constructive and functional characteristics of the technical equipment for harvesting hemp stalks and sheaf-binding and the observations on the influence of adjustments of working devices on the characteristics of hemp sheaves were presented by (*Nedelcu, A. et al., 2021*). The experiments were performed according to the methodology developed for this technical equipment and the procedures described by (*Vlăduţ, N-V. et al., 2012*).

The determination of the energy indices (working speed, fuel consumption) was done simultaneously with the indices regarding the working quality of the experimental model (actual working width, cutting height, losses on stubble field), *(Chiţoiu, M. et al., 2016; Chiţoiu, M. et al., 2017)*. Fuel efficiency varies by type of fuel and by percent load on the engine (*Grisso, R. D et al., 2004).*

The total fuel consumption in a shift depends on the hourly consumption recorded in each operating mode and the operating time in that mode, according to formula (1):

$$G_s = G_1T_1 + G_2T_2 + G_3T_3 \quad \text{[kg/shift]} \tag{1}$$

Where:

G_s – total fuel consumption in a shift, kg/shift;
G_1 – hourly fuel consumption during actual operation, kg/h
T_1 – actual operating time, h;
G_g – hourly fuel consumption while idling, kg/h
T_g – idling time, h;
G_0 – hourly fuel consumption in steady-state, kg/h
T_0 – steady-state operating time with (low speed), h;
The fuel consumption per hectare of cultivated land, G_{ha}, is determined by relation (2):

$$G_{ha} = \frac{G_s}{W_s} \quad \text{[kg/ ha]} \tag{2}$$

$$W_s = 0.36\, B_l V_l T_1 \text{ [ha/shift]} \tag{3}$$

Where: W_s - working capacity per shift, ha/shift
B_l – working width, m
B_l=1.4 m
V_l – working speed, m/s

Hourly fuel consumption G_1, for each operating mode is determined experimentally by means of a device for determining fuel consumption (accuracy ± 1 g).

G_1, depending on the energy source, can also be calculated with the relation (4):

$$G_1 = c_s P_{tr} \text{ [kg/h]} \tag{4}$$

Where:

c_s - is the specific fuel consumption, kg/ HP h;
P_{tr} – traction power, HP.

Fuel consumption for the innovative hemp stalk harvesting system was calculated based on the specific fuel consumption of the New Holland TD 80D tractor engine used in the experiments.

RESULTS AND DISCUSSION

As mentioned in the fibre crop, different seed norms were experimented, 20 kg/ha, 40 kg/ha, and 60 kg/ha respectively, the corresponding densities, determined at the 6-leaf stage, being shown in figure 5.

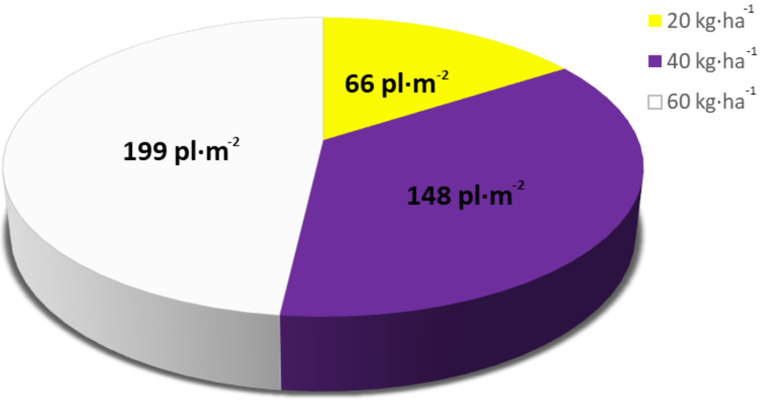

Fig. 5 - The densities corresponding to the seed norms applied in the crop for fibre

In the samples collected from the experience, biometry and agro-productivity determinations were made, depending on the cutting applied and the norm of seed/ha used, the results being summarized in the table below.

As can be seen, there is an inversely proportional relationship between the number of cuttings applied and the height of the plants, a relationship that is also found between the norm of seed applied and the height of the plants. At the same time, plant density/m^2 increases with the use of higher seed norms, while there is a direct correlation between the application of cuttings and the number of shoots formed/m^2. At the same time, the average stem diameter decreases with the application of cutting, respectively with the increase of the seed norm used per surface unit.

Table 1

Biometric and agro-productivity determinations in the harvested samples

Cutting variant	Seed norm, kg /ha	Stalk length, m	No. of plants per m^2, pc.	No. of branches per m^2, pc.	Fibre weight (g)	Fibre content (%)	Average diameter (mm)
NT	20	2.20	76	-	41	29.2	8.0
NT	40	2.10	133	-	29	30.2	6.9
NT	60	2.00	157	-	26	29.3	6.3
T1	20	1.60	60	113	21	27.1	5.6
T1	40	1.30	107	170	14	27.3	4.5
T1	60	1.20	138	192	12	27.2	4.3

According to the table below, the cutting applied to the hemp crop negatively influenced the production of stalks, the results recorded by the variant that was cut (T1 – 6706 kg/ha) being distinctly significant negative compared to the uncut control variant (11286 kg/ha), the difference from this being - 4580 kg/ha (table 2).

Table 2

Influence of cutting on stalk production

No. crt.	Variant	Production			The meaning of the differences
		average ± standard error (kg/ha)	% to the control	differences from the control	
1.	NT	11286 ± 284	100	0	Mt
2.	T1	6706 ± 448	59.42	-4580	00

DL 5% = 1269.1 kg/ha
DL 1% = 2930.8 kg/ha
DL 0.1% = 9326.6 kg/ha

In the course of the experience, the seed norm of 20 kg/ha determined statistically assured production increases at a very significant level in terms of stalk production (1251 kg/ha) compared to the control taken in the study, namely the seed norm of 40 kg/ha (8902 kg/ha), according to the results shown in the table below. The norm of 60 kg/ha registered production results below the level of the control variant, the differences being distinctly significant negative (7932 kg/ha stalks).

Table 3

Influence of seed norm on stalk production

Nr. crt.	Variant	Production			The meaning of the differences
		average ± standard error (kg/ha)	% to the control	differences from the conrol	
1.	20	10153 ± 786	114.06	1251	***
2.	40	8902 ± 1259	100	0	Mt
3.	60	7932 ± 1059	89.10	-970	00

DL 5% = 456.4 kg/ha
DL 1% = 663.8 kg/ha
DL 0.1% = 995.7 kg/ha

The combined influence of the two factors considered in the study (cutting x seed norm) on the production of stalks determined production increases that are not statistically ensured in the case of the NT x 20 combination (186 kg/ha) compared to the control Mt taken in the study - NT x 40 kg/ha (11702 kg/ha), according to Figure 6.

The combinations between the cutting applied and the three experimental norms (T1 x 20 kg/ha, T1 x 40 kg/ha and T1 x 60 kg/ha) determined differences ensured at a statistically significant negative level compared to the control of this experience (NT x 40 kg/ha – 11702 kg/ha).

Stalks productions were negatively influenced by the applied cutting and positively by the seed norm of 20 kg/ha.

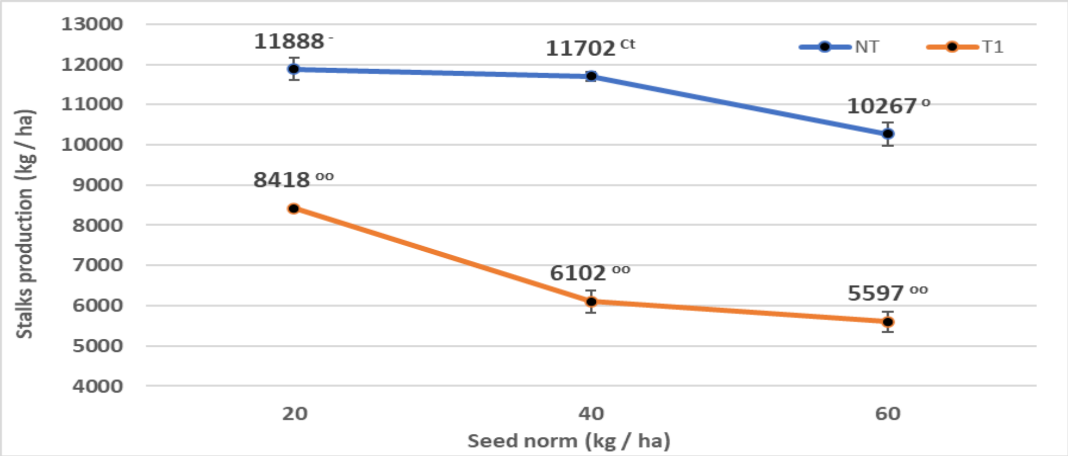

Fig. 6 - Influence of cutting and seed norm combination on stalks production

To determine the hourly fuel consumption, three measurements were made for two operating speeds of the New Holland TD 80D tractor. For the tractor engine used in the experiments, the specific consumption at rated speed was assessed, according to the operator's book:

c_s = 0,200 kg/kW h=0,176 l/CP h.

The values for the traction power consumed, used in the calculation, are presented in Table 4.

To express fuel consumption in litres/h, divide the value determined by relation (4) to diesel density which is 836 kg m^{-3} (0.836 kg/l).

Table 4

Hourly fuel consumption

Working speed, km /h	Power consumed, HP	Calculated average power, HP	Hourly fuel consumption, l/h	Average hourly fuel consumption, l/h
1.75	25.0	25.43	5.50	4.47
	25.5		5.59	
	25.8		5.68	
2.25	28.5	28.33	6.27	4.98
	27.5		6.05	
	29.0		6.38	

The norms of working capacity and fuel consumption for mechanized works for hemp stalk harvesting and binding, performed with the experimental model SRC are presented in Table 5.

Table 5

Fuel consumption per hectare

Working speed, km/h	Working capacity, ha/h	Working capacity per shift, ha/shift	Average hourly fuel consumption, l/h	Fuel consumption per hectare, l/ha
1.75	0.245	1.96	4.47	18.24
2.25	0.315	2.52	4.98	15.81

The work of stalk harvesting and sheaf-binding was carried out on flat land, with a slope of up to 60 and the production recorded for hemp crop was approx. 10 t/ha.

The value of fuel consumption per hectare of 15.81 l/ha, at a crop production of 10 t/ha, obtained with the New Holland TD 80D tractor system + harvesting and sheaf-binding equipment, SRC, compared to the value, 16.5 l/ha, indicated for the harvesting and binding machine JSK 2.1, presented in the work *Ecological agriculture technologies (Samuil, C., 2007)*, is smaller and is due to the high-performance equipment used.

CONCLUSIONS

The cutting applied to the hemp crop, for all three seed norms used, negatively influenced the production of stalks, following the comparison with the control of the experience (NT x 40 kg/ha – 11702 kg/ha); at the same time, the use of a seed norm of 20 kg/ha had a positive impact on stalk production.

The results obtained after testing the equipment presented in the paper demonstrate the fact that the fuel consumption recorded for the harvesting of hemp stalks, having a value of 15.81 l/ha, at a crop production of 10 t/ha, is lower compared to that of the equipment taken as standard JSK 2.1.

The registered results are premises for optimization of some technological links at hemp cultivation and also confirm that the fuel consumption per hectare recorded at hemp stalks harvesting is influenced both by the technical characteristics of the equipment used and by the characteristics of the harvested crop.

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