International Journal of Agriculture and Environmental Research

ISSN: 2455-6939

Volume:04, Issue:06 "November-December 2018"

PHYSIOLOGICAL STUDIES OF GROWTH, DEVELOPMENT AND YIELD IN OAT (*Avena sativa L.*)

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ABSTRACT

The aim of this research was (i) to evaluate the oat genotypes for grain yield and physiological traits, (ii) to investigate the oat genotypes having the highest grain yield in the conditions of research region and the influence of these traits on grain yield. This research was carried out using 10 oat cultivars, sown in a randomized complete block design with four replications, between 2014 and 2015 in experimental fields of ATTC Fushë Krujë, Albania. In the research, leaf area (LA), leaf area index (LAI), net assimilation rate (NAR), crop growth rate (CGR), dry matter (DM), grain yield (GY) and harvest index (HI) were investigated. According to the results obtained, cultivars were significantly different for all investigated traits. The highest grain yield 53.5 kv/ha was produced by the Torpan cultivar. Physiological growth traits (LA, LAI, NAR, and CGR) increased gradually from vegetative stage and reached maximum to booting stage. Total dry matter accumulation per plant gradually increase with crop age and attained maximum a few days before maturity. The different values of physiological growth traits impacted on different ways on grain yield. Not always the superiority of the cultivars for physiological growth traits was accompanied with high yield. This was because of different values of HI i.e. different ability to accumulate the dry matter to the grain.

Keywords: *Avena sativa*, cultivar, dry matter, grain yield, physiological growth traits

1. INTRODUCTION

In suitable conditions, all living organisms, may be grown and developed in size and structure. These processes are an important part of the plant life cycle and along with natural systems, they might contribute to distinguish living and non-living organisms [3, 6]. Even for living organisms, it is not easy to give a right definition of "growth". Growth is a vital function of plants and indicates the gradual increase in number and size of cells. The processes of growth and

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development are considered to begin with germination, followed by large complex series of morphological and physiological events [22]. Yielding ability is one of the most important quantitative characters in crop and it depends upon the yield attributing characters. Watson (1952) emphasized the importance of physiological parameters such as leaf area, leaf area duration and net assimilation rate in crop productivity. Leaf area increase contributes for canopy development. As the leaf area increases, a greater photo synthetically active surface area becomes available and it would therefore be expected that the production rate would be greater the higher the leaf area. Leaf area is indictor of potential grain yield [19] and broader and long leaves give higher grain yield in wheat [14]

Studies of growth pattern and its understanding, not only tell us how plant accumulates dry matter, but also reveal the events that can make a plant more or less productive as an individual plant or as a plant population [3,4,7, 18]. Grain yield is a complex multi component character and is greatly influenced by various environmental conditions. Various morphological and physiological characters contribute to grain yield [1,2,5, 21]. Each of these component characters has its own genetic systems. Further these yield components are influenced by environmental fluctuations [9,16, 20]. Other authors found a positive relation between dry matter yield and growth indices like CGR and LAD [22, 24]. Also, other authors reported that rice grain yield can be increased by selection on the basis of physiological growth indices like LAD, CGR, relative growth rate (RGR) and net assimilation rate (8, 10). The growth parameters like optimum LAI, LAD and NAR at flowering have been identified as the major determinants of yield [6,15,16]. A combination of these growth parameters explains different yields better than any individual growth variable [27]. Growth processes i.e. CGR, RGR and NAR directly influenced the economic yield of plant (15). Other authors [11, 12, 20] emphasize that higher accumulation of dry matter, higher LAI, LAD during reproductive stages were closely related to high yield genotypes. Thakur and Patel (1998) reported that dry matter production, LAI, LAD, CGR, NAR and RGR are ultimately reflected in higher grain yield [13]. Tasfaye et al (2006) reported that attainment of high LAI that reduces soil water evaporation, intercepts and converts into dry matter more efficiently and improves the partitioning of dry matter to the seed [20, 25]. The aim of this study was to evaluate some promising oat cultivars for their physiological growth and development and their impact on grain yield.

2. MATERIALS AND METHODS

In 2014-2015, an oat cultivars performance trial was conducted at ATTC Fushë Krujë, Albania. Ten oat varieties were evaluated for yield and physiological growth traits. The geographical location of the site is situated between 41º28'20.02" North latitude and 19º40'38.56" East longitudes. The country is situated in the central and northern part of the coastal plain to the

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Mediterranean climate, with very warm and dry summer. The soil was sub-clay layer with neutral pH, medium in available nitrogen (01.1 – 0.15%) and phosphorus (10 – 20 p.p.m.) and rich in available potassium (8 – 15 p.p.m.). In the experiment were studied ten cultivars, respectively Timer Van Gele, Torpan, Bendo, Goka, Visto, Abed Minor, Argus, Flavia, USO-32 and Këmishtaj (Local cultivar). The experimental design was a randomized complete block with four replications. The previous crop was corn. The research plots were each 10 m^2 (5 x 2m) and the seedbed was prepared by conventional tillage methods including fall plowing, and disc. Sowing was done uniformly in all the plots manually, by using 120 kg seeds/ha, with a row spacing of 20 cm. All standard agronomic practices were implemented.

Physiological growth traits were measured beginning from complete tillering to milk ripening (tillering, stem elongation, booting, and milk repining stages). Leaf area was measured in five plants as the product of the length from the base to the tip and the maximum width by using the formula suggested by Montgomery (1911).

LA (cm^2) = length of leaf (cm) x maximum width of leaf (cm) x 0.75.

Five consecutive plants selected during initial growth stages and later for measurement of leaf area, were used for dry matter accumulation studies, by measuring the wet weight and then the dry weight after drying in the thermostat (60 ° C).

The following equations were used to calculate the different physiological growth traits.

- Leaf area index (LAI) = (leaf area m^2/land area covered by plants m^2)

Net assimilation rate was calculated from dry weight and leaf area at four stages of plant growth as per the formula, Radford (1967).

- NAR (net assimilation rate NAR = $[(W_2 - W_1) / (t_2 - t_1)] \times [(\ln A_2 - \ln A_1) / A_2 - A_1)]$, (Radford, 1967) ($g/m^2$ leaf/m^2)

Crop growth rate (CGR) is the gain in weight of a community of plants on a unit of land in a unit of time and is intensively used in growth analysis of field crops. Crop growth rate was calculated at four stage of growth on dry weight basis as per formula given Radford (1967).

- CGR = $(W_2 - W_1) / (t_2 - t_1)$ (g/m^2/day)

Harvest index (HI) The data obtained from total biological yield (grain + straw) was used to calculate harvest index. Harvest index was recorded by dividing the economic (grain) yield with the total biological yield.

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HI = grain yield kv ha^{-}/Total biological yield kv ha^{-} x 100

Data were analysed using ANOVA, according to standard procedure. Comparison of the data is made with 5% significance level.

3. RESULTS AND DISCUSSION

Leaf area (LA) The leaf area in a canopy is an important variable affecting light interception, and hence photosynthesis and carbohydrate production. Our experimental data showed increase of this trait from vegetative stage to booting stage and further decreases at harvest (Fig. 1). Maximum leaf area is recorded in the cultivar Gele Van Timer (91.44 cm^2 /plant) and least in USO-32 (57.42 cm^2 /plant) (Table 1). Photosynthetic rates are positively correlated with dry matter accumulation and leaf area. As the leaf area increases till to the reproductive phase, the photosynthesis rates also increase as a result of increase demand for assimilation [2]. In fact, the decrease in leaf area at later stages of growth is due to the accelerated senescence and fall of leaves with crop age as reported by other authors [5,13].

Table 1: Maximal values of traits in different oat cultivars

Nr.	Cultivars	LA cm^2/plant	LAI m^2/m^2	CGR g/m^2/day	NAR g/m^2/m^2	TDM kv/ha	GY kv/ha	HI %
1	Gele Van Timer	91.44	7.5	17.86	3.26	141.14	42.0	29.7
2	Torpan	90.54	7.28	21.80	4.25	152.08	53.5	35.2
3	Bendo	86.49	7.25	21.05	4.04	167.22	52.0	31.1
4	Goka	79.90	7.2	21.10	3.80	160.42	52.2	32.5
5	Visto	83.12	7.3	19.80	3.50	138.68	46.7	33.7
6	Abed minor	85.61	7.76	20.95	3.95	145.53	51.6	35.5
7	Argus	75.88	7.64	19.75	3.72	178.36	47.5	26.6
8	Këmishtaj	81.77	7.37	19.85	3.63	165.03	49.5	30.0
9	Flavia	59.78	7.61	18.85	3.83	131.09	43.4	33.1
10	USO-32	57.42	7.67	20.70	3.98	146.26	44.9	30.7
11	**LSD 0.05**	**14.6**	**0.18**	**1.9**	**0.78**	**8.1**	**2.7**	**1.8**

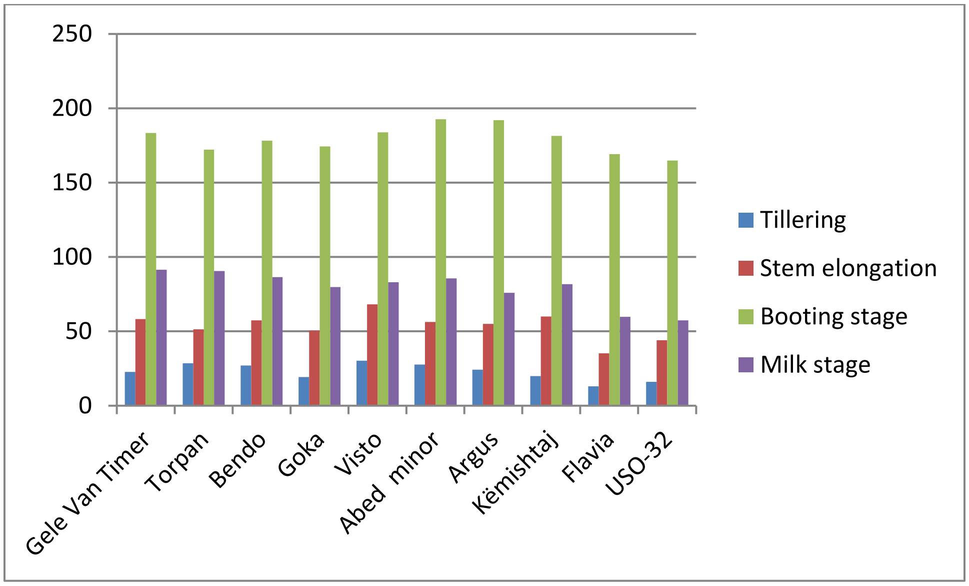

Fig. 1: The dynamics of LA change in the oat cultivars at different stages of development

Leaf area index (LAI). Leaf area index had an increasing trend till booting stage thereafter it declines (Fig. 2). This decrease in LAI might be due to leaf senescence [17]. Leaf area index is positively correlated with leaf area, and high leaf area index is due to the fast development of leaf area. Leaf area decreases at later stage and likewise the leaf area index. The initial increase of LAI was mainly related with new leaves and tillers number and its rates. The decrease of LAI after reaching a maximum was due to senescence and death of leaves in lower parts of plants. Progressive increase of LAI is associated with the increase of dry matter to a certain point [25]. The increase in LAI is closely followed by increased in canopy photosynthesis [27]. In present study LAI was maximum in all varieties up to flowering stage. For high values of LAI can be distinguished Abed minor and USO-32 cultivars, with maximal values 7.76 and 7.67 and it was found to be minimum in Goka cultivar [7.2], (Table 1).

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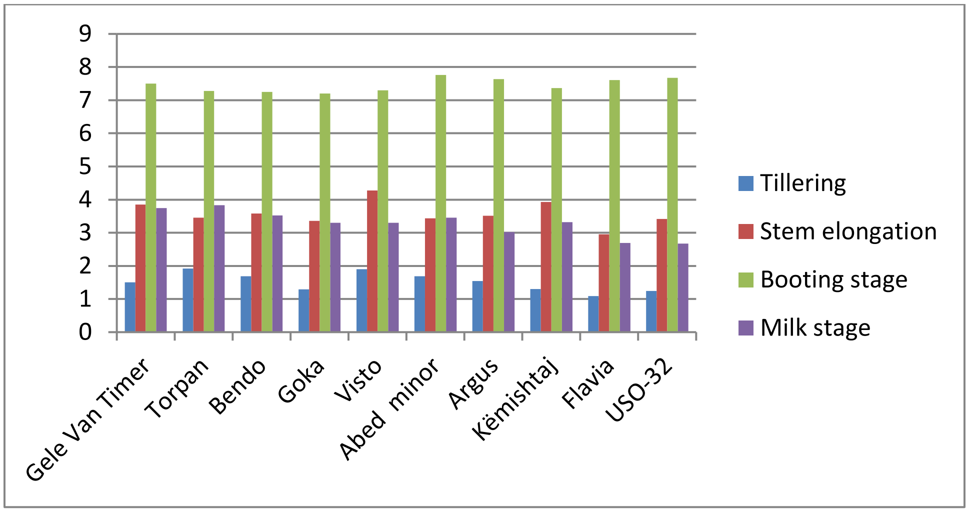

Fig. 2: The dynamics of LAI change in the oat cultivars of different stages of development

Crop growth rate (CGR). The crop growth rate simply indicates the change in dry weight over a period of time. The CGR being controlled by canopy, photosynthesis and respiration, so, it is considered more meaningful function of crop growth. The maximum crop growth rates (and hence maximum crop efficiency) are usually associated with high LAI where NAR is low. Crop growth rate gradually increased with time in all the varieties from vegetative stage to booting stage, thereafter decreased the higher values of CGR observed in Torpan and Goka cultivars with 21.8 and 21.1 g/cm^2/day respectively and lower values in Gele Van Timer and Flavia cultivars (17.86 and 18.85 respectively) (Fig. 3). The low yield of the last two cultivars (42.0 and 43.4 kv/ha respectively) indicated that they were less efficient per unit of leaf area. The results were in line to the findings of Valero et al., [22] who reported that lowest CGR values were recorded during early vegetative growth stage.

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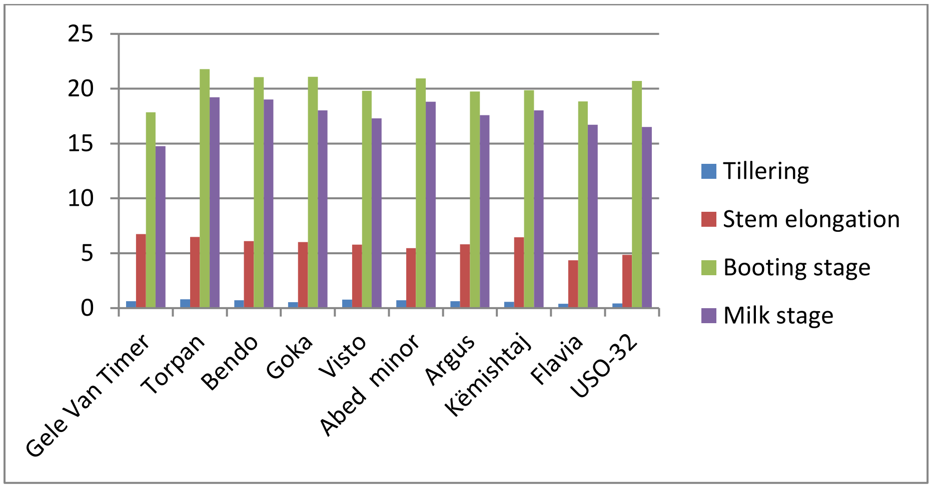

Fig. 3: The dynamics of CGR change in the oat cultivars at different stages of development

Net assimilation rate (NAR). NAR is a measure of the rate of dry matter accumulation per unit leaf area. This attribute was also significantly during the vegetative and reproductive stage for all cultivars. The maximum NAR values for all cultivars are observed at flag leaf stage and thereafter it declined sharply (Fig. 4). The maximum NAR figure at flag leaf can be attributed by higher leaf area. Similar results were reported by Yang et al., Gele Van Timer cultivar had minimum net assimilation rate as compared to all other genotypes (Max NAR 3.26 g/m$^{2/}$day), and Torpan and Bendo cultivars had maximum net assimilation rate (max NAR 4.25 and 4.04 respectively). (Fig. 4). Low NAR might be due to restricted availability of essential nutrients, decreased photosynthetic efficiency [2] or lower rate of biomass production. Although [22] reported higher values for NAR during early vegetative growth but a decline during the latter stages, a situation which the authors attributed to a general decline in photosynthetic efficiency with leaf age and also perhaps to lack of nutrients in later stages, our results revealed that NAR values were higher during vegetative phase than at flowering phase. The difference between the two studies might be due to the fact that the authors extended their sampling till harvest time while we stopped sampling at flowering.

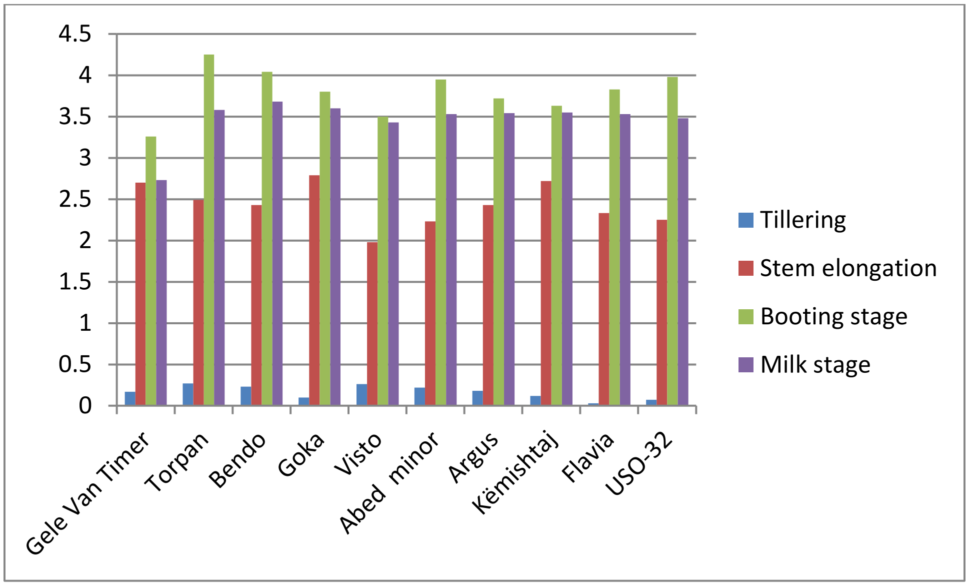

Fig. 4: The dynamics of NAR change in the oat cultivars at different stages of development

The dry matter accumulation. The dry matter accumulation expresses the potential opportunity of a cultivar for a particular product [3,21]. Rate of dry matter accumulation during early development is directly related to LAI. The increase in LAI, and, consequently, the increase in rate of dry matter accumulation, is proportional to rate of dry matter accumulation per unit leaf area (NAR). Total dry matter accumulation per plant gradually increase with crop age and attained maximum a few days before maturity (Fig. 5). From this moment rates of dry matter accumulation per day start to decline due to aging during the final phase of development. The decline in the rate of dry matter accumulation during this phase is associated with functional and visual leaf senescence. Functional leaf senescence is the decline in photosynthesis per unit leaf area due to aging.

ISSN: 2455-6939

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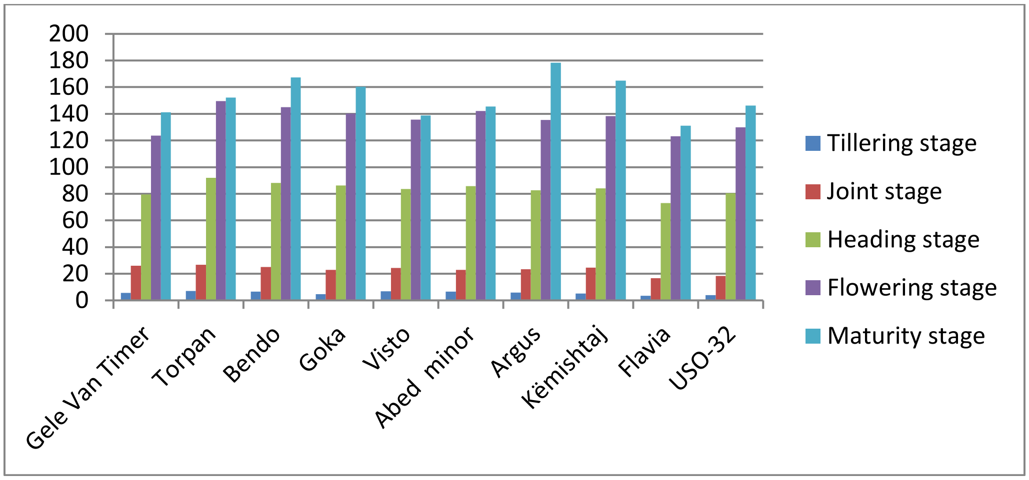

Fig. 5: The dynamics of dry matter accumulation change in the oat cultivars at different stages of development

In the present study, more dry matter accumulates Argus, Bendo and local cultivar Kemishtaj 178.36,167.22 and 165.03 kv/ha respectively (Tab 1). The above results indicated that, there was a significant difference between the genotypes in dry matter allocation and partitioning of the photo-assimilate allocation. But the accumulation intensity of dry matter of cultivars changes in two periods, tillering-heading and heading- maturity. So in the first period the amount of dry matter is higher to Torpan, Bendo and Goka cultivars (92.04, 88.09 and 86.17 kv/ha respectively), while in the second period (heading-maturity), this indicator is higher in above mentioned cultivars (Fig 6) This fact can be explained by architectural construction of plant in these cultivars, characterized by excessive vegetative growth in the first stage of growth, which does not always lead to a higher grain yield. The cultivars Argus and Bendo, have a higher effectiveness of the use of dry matter production in favour of grain production.

Grain yield (GY). As average the highest grain yield (53.5 kv/ha) was obtained from Torpan variety. Goka (52.2 kv/ha), Bendo (52.0 kv/ha) and Abed minor (51.6 kv/ha) varieties were also higher than the others and those cultivars were placed in to the same group with Torpan variety. Varieties above mentioned, compared to the average yield of all the other varieties (45.7 kv/ha) were provided higher GY at the rate 17.1%. 14.2%. 13.7% and 12.9% respectively. As the average the lowest grain yield (42 kv/ha) was obtained from Gele Van Timer variety. Other varieties Flavia (43.4 kv/ha) and USO-32 (44.9 kv/ha) also were placed in the same group with Gele Van Timer variety (Fig. 6). The remaining varieties including local variety Këmishtaj occupy an intermediate place between the two groups. The differences in yield among the genotypes grown in the same environment were due to genetic influences. In general, grain yield of cereals is directly dependent on sink size (seed number and seed weight) and on the efficiency of the genotypes in the partitioning of assimilates to the grain (harvest index) and values of physiological traits during growth period. An increase in NAR during the growth period is an indication of the response of the apparatus due to increased assimilation requirements to allow fast growth of the plant (Valero et al., 2005). In our study, it has been noted that not always the superiority of the cultivars for physiological growth traits was accompanied with high yield. For example, Argus cultivar had high values of LA, LAI and TDM, but their grain yield is in medium level. This is because Argus cultivar has the lowest value of HI i.e. low ability to accumulate the dry matter to the grain.

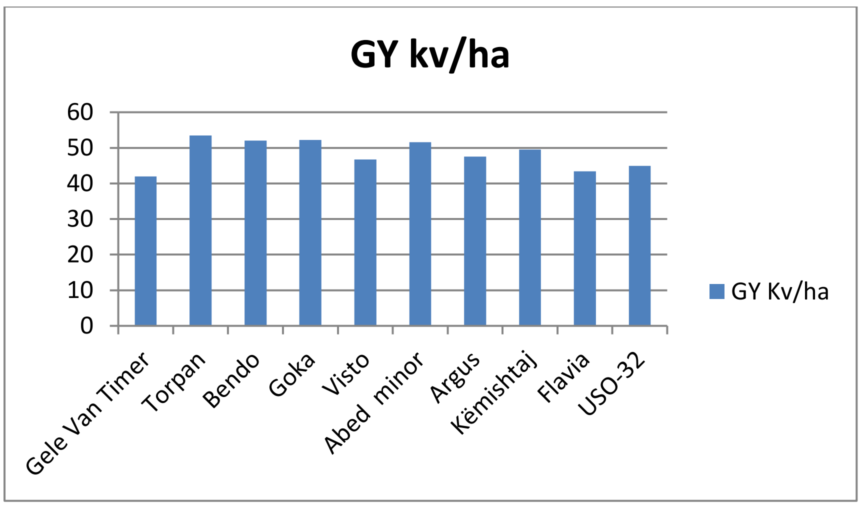

Fig. 6: The grain yield of different oat cultivars

The data obtained show that different physiological growth traits have influenced differently on grain yield. It seems clear that the high yield of Torpan and Bendo cultivars is a result of the high NAR values, whereas in the Abed minor cultivar, high values of LA, LAI and HI seemed to be determinant.

It is interesting to note that the lower yield of Gele Van Timer cultivar was associated with lower values for almost all physiological growth traits. Other cultivars such as Argus and Këmishtaj, although had high values of physiological traits, was not distinguished for high yield due to a physiological "defect" relates to the way of partitioning of dry matter accumulation

Harvest index (HI). Significant differences in harvest index were shown for the cultivars grown in experiment (Table 1). The HI values ranged from 26.6 to 35.5 %, indicating that this group of cultivars partition different quantities of assimilates to the grain. Possible explanations for the disparity are: ***1).*** The cultivars developed different amounts of vegetative tissue in the fruiting

ISSN: 2455-6939

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structure (panicle), ***2).*** The cultivars had greater photosynthetic capacity near the end of the grain filling period (i.e., beyond 150 days after planting), ***3).*** The cultivars had greater efficiency of the transport system near the end of grain filling, ***4).*** The cultivars may have stored larger quantities of assimilates in the stems before grain filling and then remobilized or transported more of them to the maturing grain (Fig. 7).

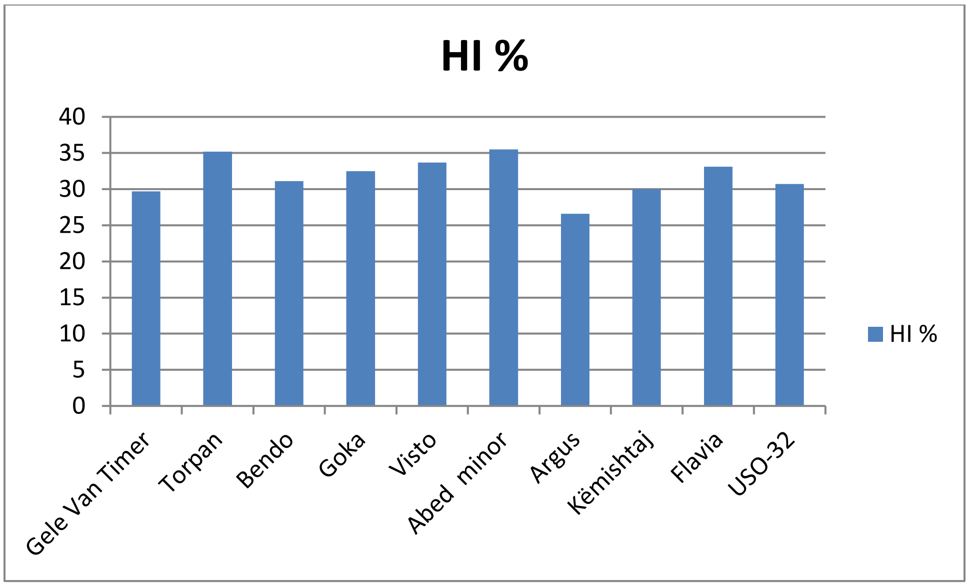

Fig. 7: The harvest index of different oat cultivars

4. CONCLUSIONS

Based on the results of experiment it may be concluded that under Albanian conditions were observed significant ($p<0.05$) differences between oat cultivars in study for grain yield, dry matter accumulation and physiological growth traits. The highest grain yield was obtained from Torpan, Goka and Bendo. High grain yield of Torpan and Bendo was associated with high physiological growth traits, but not always the superiority of the cultivars for these traits was accompanied with high yield. This was because of different values of HI i.e. different ability to accumulate the dry matter to the grain.

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