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THE EFFECT OF SOWING QUANTITY AND ROW SPACING ON SEED PRODUCTION OF FEW MINOR GRASS SPECIES

ABSTRACT

A wide range of seed material from different grass species is necessary to keep high quality grasslands and to create buffer zones between arable lands and forest and to re-cultivate waste or fallow land. Therefore, the aim of our research was to describe elements of seed propagation of some minor grass species. On the basis of field experiments, different spacing and seed quantities were investigated for *Beckmannia eruciformis, Cynosurus cristatus* and *Elytrigia elongata* aiming at an optimal seed production. Satisfying seed yields were obtained even at a reduced (50% to 75%) amount of seed quantity, as compared to theoretical (or normal) values, calculated on the basis of number of plants per area unit.

Key words: *Beckmannia, Cynosurus, Elytrigia elongata*, seed yields,

INTRODUCTION

European semi-natural grasslands are a result of long, stable utilization of lowland and mountain areas for hay and as a pasture. Their botanical composition was extremely rich since the absence of fertilization enabled the presence of many low-growing species (Scotton *et.al.* 2012). Recent changes in agriculture, with the use of mineral fertilizers, mechanization, drainage and the introduction of highly selected varieties of forage species, led to a significant changes of grassland ecosystems with for example reduction of species and varieties used. The trade of forage grasses is domi-

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nated by ryegrasses (*Lolium* sp.), fescues (*Festuca* sp.), timothy (*Phleum* sp.) and cocksfoot (*Dactylis* sp.). However, there is much less information (and seed material) available for many indigenous grass species, although some undoubtedly have many desirable qualities and are well suited to specific ecological or management situations (Peeters *et al.* 2004). In addition to forage production, the need to maintain biodiversity, soil erosion control, carbon sequestration, watershed protection etc. are subjects that should receive increasing attention (Gibson 2009).

Multiplication of sufficient amount of seeds of different so called 'minor grasses' and their use for regeneration of native, species-rich meadow swards could be used as a possible way of increasing biodiversity. The term 'minor grasses' refers to the degree of attention paid to these species by scientists, plant breeders and by commercial sector etc. (Żurek and Sevcikova, 2010). Species as *Beckmannia eruciformis, Briza media, Trisetum flavescens, Pucinellia distans* or *Cynosurus cristatus* are no longer part of breeding activities, and there is lack of available and variable seed material (Krzymuski *et al.* 2003). In the past decades the importance of minor grasses has also increased as a response to the public interest in restoration of disturbed landscapes (Scotton *et al.* 2012). Commercially available, highly productive grass mixtures are effective only in intensive forage and pasture management, while for areas of lower soil quality, disturbed water conditions or high salinity it is not possible to use only *Lolium, Dactylis* or *Festuca* forage varieties. As far as we are able to use relatively wide range of species, we can try to improve quality and biodiversity of many of agricultural lands.

From the wide range of minor grass species three following species were selected for our experiment: *Beckmannia eruciformis* (L.) Host, *Cynosurus cristatus* L and *Elytrigia elongata* (Host) Nevski (syn. *Elymus elongatus*, *Thinopyrum ponticum*, *Agropyron elongatum*).

Beckmannia eruciformis (sloughrass) is an Eurasian continental species with a wide distribution range in Europe and Asia. Within Central Europe it has been recorded only from south-eastern Slovakia, north-eastern Poland and northern and eastern Hungary (Ciosek *et al.* 2008, Dite *et al.* 2011). This species was cultivated before II World War and has no significance in farming nowadays (Ciosek *et al.* 2008). *Beckmannia* is best adopted to poorly drained, irrigated, and somewhat acidic to alkaline soils with shallow water tables. It performs best on clay soils covered with a thin layer of organic matter, but grows on a coarser substrates as well. In USA it is recommended for waterfowl habitat and reclamation and erosion control plantings in seasonally wet areas as ditches, stream banks, or fresh water shorelines (Darris *et al.* 2004).

Cynosurus cristatus (crested dog's tail) is native to Europe and the Caucasus. It is a common grassland species, found predominantly in pastures, but also in old meadows (Żurek and Sevcikova 2010). *Cynosurus* grows well on a large range of soil nutrient availability except the richest and the poorest soils, mainly acid to neutral. It has preferences for clay, loam and sandy-clay soils (Peeters *et al.* 2004). It likes fairly well-drained soils and does not tolerate water-logging very well; it withstands light traffic and is often found along footpaths and tracks through grasslands. *Cynosurus* has good production when grazed on poor soils with low N fertilization. Can play a secondary role in extensive or moderately intensive grasslands (Peeters *et al.* 2004). Only a few commercial varieties are currently present on OECD list, but none for Poland (OECD 2012).

Elytrigia elongata (tall wheat grass) is Pontic-Mediterranean grass species, distributed along the Mediterranean Basin from Black Sea to the Iberian Peninsula (Csete *et al.* 2011). It is adapted to a wide range of soil types and climates. It is often recommended for sites with high water tables. Tall wheatgrass is one of the most saline or alkali tolerant grasses. It can tolerate up to 1% soluble soil salts. It is also recommended for erosion control along roadsides and other critical areas (Scheinost *et al.* 2008). Tall wheat grass is also promising bioenergy species (Csete *et al.* 2011, Martyniak *et. al* 2011). Except some commercial varieties breed for USA, Argentina or Hungary, none is currently available for Poland (OECD 2012).

Knowledge of the basic recommendations for seed production as for example sowing quantity and row spacing is necessary to improve the effectiveness of mentioned agricultural activity. Therefore, the aim of the current research was to discover the effect of sowing quantity and row spacing on seed production on the example of three minor grass species mentioned above.

MATERIAL AND METHODS

Seed material was kindly provided by the Polish Genebank, PBAI - NRI. A field trail was established in 2009 in Radzików, Poland. *Elytrigia* originated from Ukraine, while *Beckmannia* and *Cynosurs* from Poland. Soil used for experiment was sandy loam. Detailed soil analysis was performed by The Regional Agro-Chemical Station and summarized in Table 1. The experimental design included three replicates with two treatments - three levels of sowing quantities and two different row spacing: 15, 7.5, 4.0 kg·× ha^{-1} and 25 and 50 cm for *Elytrigia*, 16, 8.3, 4.1 kg × ha^{-1} and 20 and 30 cm for *Beckmannia*, and 10, 5 and 2.4 kg × ha^{-1} and 15 and 25 cm for *Cynosurus*, respectively. The dimension of single plot of each species per treatment and per replication was 2 m^2. Seed quantities were established at three levels: normal, ca. 50% less than normal and ca. 75% less than normal. ‘Normal’ quantity was calculated for 75 plants for *Elytrigia elongata*, 500 plants for *Beckmannia eruciformis* and 1000 plants for *Cynosurus cristatus* per 1 m^2 of plantation. Mentioned values were calculated after Martyniak and Martyniak (2002) and Martyniak (2005). Fertilization was applied in Spring (60 kg N·× ha^{-1}) and in Autumn (80 kg of P and K·× ha^{-1}) each year.

Table 1

Soil analysis results before the experiment set up. (analysis performed by the Regional Agro-Chemical Station)

Soil parametr:	Value / unit
Sand (> 0.02 mm)	79.67 %
Silt (0.02 - 0.002 mm)	20.30 %
Clay (< 0.002 mm)	0.0 %
SOM	1.46 %
pH	5.73
Chemical compounds	[mg × kg^{-1} of soil]
N (NO_3)	8.0
N (NH_4)	17.7
P	152.0
K	186.7
Ca	420.0
Mg	43.0
Cl	14.3
Cu	3.2
Fe	120.8
Mn	12.0
Zn	7.9

After three months from sowing in 2009 initial plant density (IPD) was counted and expressed as a number of plant per 1 m of row. Following traits were further measured and observed in 2010 and 2011: overwintering (OW, 1 – 9 scale, where 1 is dead plants), beginning of heading date (HE, no. of days from the 1 of April to that moment when on 30% of plants per plot of particular species emerged tillers were visible but not less than 3 tillers per plant), beginning of flowering time (FL, no. of days from the 1 of April to the moment when on 30% of plants per plot of particular species symptoms of flowering i.e. anthers were visible), plant height at flowering time (PH, in cm), number of seed heads per 1 m^2 (SH), lodging (LD, in 1 – 9 scale, where 1 means plants lying flat on the ground), rust susceptibility (RUST, 1 – 9, where 1 means plants completely dead) and seed yield (SY, t·ha^{-1}). Seed harvest was performed manually at full ripening phase for each species. The harvest always began when gentle hand rubbing of spikes resulted in evident seed shattering. *Beckmannia* seed were harvested since the sowing year (2009, 2010 and 2011), and other species since the 1-st year after sowing. Seed-related traits (thousand seed weight – TSW, seed germination after 1-st and 2-nd count – G_1, G_2) were also determined. Each year, 3 – 4 month after the harvest, seeds (3 representative samples of 300 seeds, per treatment from each species) were placed on Petri dishes on filter paper, soaked with demineralized water and placed into the refrigerator (+ 5°C) for 5 days. Further, seeds were germinated according to gene banks recommendations (Ellis *at al.* 1985). Climatic conditions during the course of experiment were recorded by automatic Vaisala HydroMet™ System MAWS 101 located ca. 0.3 km from experimental plots (Table 2). Statistical calculations were made according to SAS® statistical package. The least significant differences (LSD) between means were calculated according to the Fisher honesty test and significance of difference was tested with the probability of 95%.

Table 2

Weather conditions during the period of experiment and differences (*diff.*) from the 1971 – 2000 mean

Month		Mean temperature [°C]			Rainfall [mm]		
		Year			Year		
		2009	2010	2011	2009	2010	2011
January	value	-	-8.4	-0.4	-	0.4	29.0
	diff	-	*-6.5*	*1.5*	-	*-20.9*	*7.7*
February	value	-	-1.8	-3.8	-	37.2	21.8
	diff	-	*-0.7*	*-2.8*	-	*19.7*	*4.3*
March	value	3.1	3.3	3.3	47.2	12.4	14.0
	diff	*0.3*	*0.5*	*0.5*	*24.9*	*-9.9*	*-8.3*
April	value	11.3	10.1	11.0	14.8	12.6	40.8
	diff	*3.2*	*1.9*	*2.8*	*-15.5*	*-17.7*	*10.5*
May	value	13.7	13.7	14.7	71.8	149.6	37.6
	diff	*-0.5*	*-0.5*	*0.5*	*25.8*	*103.6*	*-8.4*
June	value	16.3	17.8	18.9	84.0	64.6	52.8
	diff	*-0.6*	*0.9*	*2.0*	*21.0*	*1.6*	*-10.2*
July	value	20.0	21.7	18.2	138.6	131.6	292.2
	diff	*1.5*	*3.2*	*-0.3*	*64.3*	*57.3*	*217.9*

Table 2

Continued

Month		Mean temperature [°C]			Rainfall [mm]		
		Year			Year		
		2009	2010	2011	2009	2010	2011
August	value	18.5	19.8	19.0	81.4	61.0	144.2
	diff	*0.3*	*1.7*	*0.8*	*29.6*	*9.2*	*92.4*
September	value	15.4	12.5	15.2	12.8	85.6	4.6
	diff	*2.1*	*-0.8*	*1.9*	*-30.8*	*42.0*	*-39.0*
October	value	7.8	6.0	-	35.0	15.2	-
	diff	*-0.6*	*-2.3*	-	*3.5*	*-16.3*	-
November	value	6.0	5.8	-	58.0	100.0	-
	diff	*3.2*	*2.9*	-	*27.6*	*69.6*	-
December	value	-1.1	5.6	-	46.2	39.2	-
	diff	*-1.0*	*5.7*	-	*17.8*	*10.8*	-
Apr-Sept.	value	15.9	15.9	16.2	403.4	505.0	572.2
	diff	*1.0*	*1.1*	*1.3*	*94.5*	*196.1*	*263.3*

RESULTS AND DISCUSSION

Among all sources of variation (species, sowing quantity and row spacing) only for species used in experiment significant difference for all examined traits were noted (Table 3). Spacing had no effect on any trait and sowing quantity significantly affected only initial plant density and lodging. When species were sown at lower quantities (2.4, 4.0 and 4.1 kg·× ha^{-1} for *Cynsourus*, *Elytrigia* and *Beckmannia*, respectively), plant density was lower and lodging value was higher is sown at higher quantities (Table 4). It was found in many research that sparsely sown plants had the best mechanical parameters of steam for resistance to lodging (Pinthus 1973; Skubisz, 1996; Simic *et al.* 2009).

The highest seed yields were obtained for *Beckmannia eruciformis* (Table 5). Moreover, only *Beckmannia* produced fertile inflorescence and viable seed in the sowing year. Seeding rates used in our experiment for *Beckmannia* were similar to USDA recommendations for this species (4 to 16 kg·× ha^{-1}, depending on the site and purpose of planting) (Darris *et al.*

2004). It has to be mentioned that after three or four years of satisfying seed yields, *Beckmannia* usually drastically degrades and it is necessary to renew the plantation (Martyniak, personal communication). For *Cynosurus cristatus* the period for seed production is even shorter (probably due to serious rust infection), whereas *Elytrigia* plantation can be used much longer for seed propagation (5 – 7 years).

Table 3

Analysis of variance for the effect of species, row spacing and sowing quantity and their interactions on traits examined (2010 – 2011 means). Error mean squares and the significance of the effect at: ** - P < 0.05, ***, P < 0.001

Source of variation	OW [1]	PH	SH	LD	RUST	SY
species (1)	34.09 ***	113410.41 ***	3517328.3 ***	25.38 ***	167.75 ***	3.33 ***
row spacing (2)	0.35	9.88	11024.3	0.57	0.11	0.01
sowing quantity (3)	0.20	2.27	126371.5	4.48 ***	0.33	0.00
interaction 1 x 2	0.68	10.54	77821.3	0.28	0.36	0.04
interaction 1 x 3	0.82	15.05	21056.9	0.06	0.14	0.04
interaction 2 x 3	0.11	42.96	3331.7	0.01	0.02	0.01
interaction 1 x 2 x 3	0.26	43.78	44824.8	0.21	0.06	0.01

[1] trait symbols refer to descriptions given in 'Material and methods' section

Table 4

Results of measurements and observation excluding seed yield (2010-2011 means)

Genus, species (A)	Sowing quantity (B) [kg × ha^{-1}]	Row spc. (C) [cm]	Traits measured and observed[1]							
			IPD	HE	FL	OW	PH	SH	LD	RUST
Elytrigia elongata	15.0 (normal)	25	126.0	86.0	94.0	7.0	180.0	426.7	5.3	9.0
	7.5 (50% less)		98.6	87.5	94.0	6.7	181.7	492.0	5.3	9.0
	4.0 (74% less)		50.6	87.0	95.0	6.0	190.0	434.7	6.0	9.0
	15.0 (normal)	50	126.0	86.5	98.0	6.0	180.0	586.7	5.7	9.0
	7.5 (50% less)		85.4	87.0	97.0	5.3	186.7	714.7	5.7	9.0
	4.0 (74% less)		66.0	86.0	96.0	4.7	188.3	736.0	6.3	9.0
	LSD for B		43.18	ns.	ns.	ns.	ns.	ns.	ns.	ns.
	LSD for C		ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.

Table 4

Continued

Genus, species (A)	Sowing quantity (B) [kg × ha^{-1}]	Row spc. (C) [cm]	Traits measured and observed[1]							
			IPD	HE	FL	OW	PH	SH	LD	RUST
Beckmannia eruciformis	16.0 (normal)	20	156.6	54.0	67.5	3.3	106.7	1266.7	6.7	6.3
	8.3 (47% less)		121.4	57.0	68.5	3.0	105.0	1179.3	7.0	7.0
	4.1 (74% less)		61.4	55.0	68.5	3.3	110.0	1074.3	7.7	7.0
	16.0 (normal)	30	205.4	56.0	68.5	4.0	105.0	1025.3	6.7	6.7
	8.3 (47% less)		178.6	56.0	69.5	3.7	106.7	1148.0	7.0	6.7
	4.1 (74% less)		80.0	55.5	68.5	3.3	106.7	1182.0	8.0	6.7
	LSD for B		43.48	ns.	ns.	ns.	ns.	ns.	0,59	ns.
	LSD for C		ns.	ns.	ns.	ns.	ns.	ns.	n.s.	ns.
Cynosurus cristatus	10.0 (normal)	15	250.0	49.0	66.0	5.0	88.3	1536.0	7.0	4.0
	5.0 (50% less)		125.4	50.0	67.5	5.3	88.3	2040.0	7.0	4.3
	2.4 (76% less)		60.0	51.0	67.0	5.7	88.3	2008.0	8.0	4.7
	10.0 (normal)	25	252.0	51.5	67.0	5.7	91.7	1580.0	7.0	5.0
	5.0 (50% less)		153.4	52.0	68.0	5.7	88.3	1736.0	7.7	4.7
	2.4 (76% less)		91.4	51.5	66.5	6.0	91.7	1645.3	8.0	4.7
	LSD for B		38.1	ns.	ns.	ns.	ns.	ns.	ns.	ns.
	LSD for C		ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.
All species:	LSD for A		41.73	1.89	1.90	0.47	4.86	199.4	0.38	0.29
	LSD for B		31.19	ns.	ns.	ns.	ns.	ns.	0.48	ns.
	LSD for C		ns.	ns.	ns.	ns.	ns.	ns.	ns.	ns.

[1] trait symbols refer to descriptions given in 'Material and methods' section. **. *** - significance of difference at a 0.05 and 0.001

Different relations between traits observed and seed yield for each species were calculated (Table 6). Significant and positive correlation coefficients between seed yield and number of seed heads per 1 m^2 were calculated for *Beckmannia* and *Cynosurus* but not for *Elytrigia*. The number of reproductive tillers per unit area is an important component in establishing the seed yield potential; however, its importance varies among grass species (Boelt and Studer, 2010). For lodging significantly negative correlations coefficients with SY were calculated also only for *Beckmannia* and *Cynosurus*. Generally, for SY of *Elyrtigia* significant correlation coefficient was calculated only for OW.

Table 5

Seed yields from three grass species used in experiment

Genus, species (A)	Sowing quantity (B) [kg × ha^{-1}]	Row spacing (C) [cm]	Seed yield in years: [t × ha^{-1}]			Cumulated (2009+2010+2011)
			2009	2010	2011	
Elytrigia elongata	15.0 (normal)	25	0	0.87	0.54	1.41
	7.5 (50% less)		0	0.93	0.56	1.49
	4.0 (74% less)		0	0.74	0.57	1.31
	15.0 (normal)	50	0	0.75	0.69	1.45
	7.5 (50% less)		0	0.62	0.55	1.17
	4.0 (74% less)		0	0.63	0.81	1.44
	LSD for B		-	n.s.	n.s.	n.s.
	LSD for C		-	n.s.	n.s.	n.s.
Beckmannia eruciformis	16.0 (normal)	20	0.71	1.53	0.74	2.97
	8.3 (47% less)		0.44	1.65	0.84	2.94
	4.1 (74% less)		0.46	1.58	0.86	2.89
	16.0 (normal)	30	0.54	1.52	0.65	2.70
	8.3 (47% less)		0.43	1.57	0.81	2.81
	4.1 (74% less)		0.44	1.49	0.80	2.72
	LSD for B		n.s.	n.s.	n.s.	n.s.
	LSD for C		n.s.	n.s.	n.s.	n.s.
Cynosurus cristatus	10.0 (normal)	15	0	0.92	0.31	1.23
	5.0 (50% less)		0	0.86	0.29	1.15
	2.4 (76% less)		0	0.81	0.26	1.07
	10.0 (normal)	25	0	0.95	0.32	1.28
	5.0 (50% less)		0	1.02	0.28	1.30
	2.4 (76% less)		0	0.89	0.31	1.20
	LSD for B		-	n.s.	n.s.	n.s.
	LSD for C		-	0.09	n.s.	0.09
All species:	LSD for A		-	0.11	0.09	0.13
	LSD for B		-	n.s.	n.s.	n.s.
	LSD for C		-	n.s.	n.s.	n.s.

Table 6

Correlation coefficients between seed yield (SY. mean 2010-2011) and other traits measured

Traits [1]	*Elytrigia*	*Beckmannia*	*Cynosurus*
OW	0.40**	-0.80***	0.85***
PH	-0.24	-0.37**	-0.16
SH	-0.29	0.89***	0.85***
LD	-0.23	-0.54**	-0.68***
RUST	0.21	-0.25	0.19

[1] trait symbols refer to descriptions given in 'Material and methods' section. **. *** - significance of difference at a 0.05 and 0.001

Seed yields of the above mentioned grass species were not estimated frequently. Duke (1983) reported that *Elytrigia* variety 'Orbit', cultivated in USA, yielded between 0.38 and 0.72 $t \cdot \times ha^{-1}$ which is quite similar to our results. According to breeder's information about variety 'Roznovska' of *Cynosurus* seed yield may range between 0.5 – 1.0 $t \cdot \times ha^{-1}$, however obtained at a sowing quantity 18 – 20 $kg \cdot \times ha^{-1}$ (OSEVA PRO, 2011). It is therefore reasonable to reduce the seed quantity according to our data. *Beckmania* is currently rare in Poland therefore information considering seed yields are not available. Despite of two cultivars developed and registered in Poland before the Second World War, nothing has been done with seed production of *Beckmannia* (Krzymuski *et al.* 2003).

Sowing quantity and row spacing had no significant effect on the quality of seed harvested (Table 7). Calculated significant differences resulted from genetic differences between species. Seed quality is usually mostly affected by climatic conditions during vegetative phase, inflorescence initiation, development, pollination and fertilization and finally, seed formation (Boelt and Studer, 2010; Griffiths *et al.* 1978). Considering all results of mean HE and FL dates no significant differences were noted between years of experiment. The most critical periods for seed quality (pollination, fertilization and seed formation) occurred in June/July (for *Beckmannia* and *Cynosurus*) and in July (for *Elytrigia*). Considering weather conditions during the course of above mentioned period, precipitation in 2011 was much higher than in 2010 (Table 2). For example, in July of 2011 only 8 days without rain event were noted, while in 2010 – 18. Generally, total rainfall for the whole vegetation period in 2011 (April – September) exceeded normal value of 263.3 mm. For 2010 it was only 196.1 mm, and distributed more evenly across season (cv_{2010} = 59.6%, cv_{2011} = 112.4%). Such uneven distribution of precipitation across vegetation season in 2011 could probably reduce seed quality.

Table 7

Mean values of thousand seed weight (TSW) and seed germination (G_1, G_2) (standard deviations in italics and parenthesis). Analysis of variance of the effect of years, species, row spacing and sowing quantity and their interactions on TSW, G_1, and G_2. Error mean square values and significance of the effects (* - significance of the effect at P < 0.001)**

Genus species	Harvest year	Seed-related traits:		
		TSW (g)	G1 (%)	G2 (%)
Mean values:				
Elytrigia elongata	2009	-	-	-
	2010	7.86 (*0.415*)	91.0 (*1.85*)	93.2 (*3.98*)
	2011	8.06 (*0.245*)	71.5 (*3.11*)	83.4 (*3.29*)
Beckmannia eruciformis	2009	0.93 (*0.23*)	72.8 (*3.49*)	79.7 (*4.27*)
	2010	0.92 (*0.22*)	51.7 (*2.30*)	72.7 (*2.33*)
	2011	0.98 (*0.06*)	43.9 (*3.46*)	73.8 (*3.73*)
Cynosurus cristatus	2009	-	-	-
	2010	0.40 (*0.07*)	71.2 (*2.18*)	83.4 (*3.29*)
	2011	0.39 (*0.02*)	54.2 (*3.25*)	73.9 (*2.34*)
Analysis of variance:				
Effect of:years (1)		0.15	5848.33 ***	987.77 ***
Effect of:species (2)		630.14 ***	10002.36 ***	2054.27 ***
Effect of:row spacing (3)		0.15	6.95	0.00
Effect of:sowing density (4)		0.01	3.21	3.88
Only significant interactions	(1) x (2)	0.09	342.16 ***	352.59 ***
	(1) x (2) x (4)	0.13 ***	1.38	4.04

CONCLUSIONS

- Tested grass species were different in seed yield quantity and quality.
- Differences observed were mostly of the genetic nature modified by climatic factors, mostly by precipitation.
- Sowing quantity and row density has no effect on seed yield of tested grass species.
- It is possible to obtain satisfying yields of tested species even at a reduced (50% to 75%) amount of seed sown.

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