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# Plant Gene

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## Phylogenetic analysis and expression profiling of Nuclear Factor-Y gene family in Dendrobium catenatum Lindl. (Orchidaceae)

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A R T I C L E I N F O	A B S T R A C T
Editor: A Rooney	Nuclear factor-Y (NF-Y) are transcription factors that play vital role in various developmental processes such as
Keywords: NF-Y Dendrobium catenatum Orchidaceae	flowering, embryogenesis, root formation, nodulation and stress tolerance. In the present study, 27 <i>NF-Y</i> genes were identified in <i>Dendrobium catenatum</i> which were grouped into three sub-families: DcNF-YA (5), DcNF-YB (10) and DcNF-YC (12), on the basis of presence of specific conserved domains. The phylogenetic relationship between DcNF-Y protein sequences with their orthologs in <i>Vanilla planifolia</i> and <i>Arabidopsis thaliana</i> confirmed the classification of these proteins into the specified three groups. Physico-chemical characterization reported a wide range in the protein length (111 to 433 amino acids), with DcNF-YAs being longer than the others. Strong interaction between most of the DcNF-Y proteins suggests towards the formation of complexes which might be playing a role in different developmental processes. Gene architectural studies predicted the presence of multiple (3–6) introns in <i>DcNF-YA</i> in contrast with the intron-less status of majority of <i>DcNF-YB</i> genes. Indicate the potential of threes organs in etrace tolerange. Additionally, using he promoter regions of <i>DcNF-YB</i> genes indicate the potential of theres organs in etraces tolerange.
	towards their widespread role in growth and development. This work can act as a harbinger for functional

characterization of NF-Y genes with a view for genetic improvement in Dendrobium catenatum Lindl.

## 1. Introduction

Nuclear factor-Y (NF-Y) is a class of transcription factor that play decisive role in diverse developmental pathways in plants. These are also present in other eukaryotes as CCAAT-binding factor (CBF) or heme activator protein (HAP). NF-Ys are composed of three sub-families i.e. NF-YA, NF-YB and NF-YC, so named due to presence of specific subunits. The NF-YB is further sub-grouped into LEC (Leafy cotyledon) and non-LEC categories. Each NF-Y protein contains a centrally conserved domain for DNA binding and sub-unit interactions. NF-Y are represented by single gene in yeast and mammals while it is encoded by multiple genes in plants (Petroni et al., 2012). This gene family has been characterised in various plants such as Arabidopsis thaliana (30; Petroni et al., 2012), Brachypodium distachyon (36; Cao et al., 2011), Camellia sinensis (35; Wang et al., 2019), Citrus grandis (24; Mai et al., 2019), Cucumis sativus (27; Chen et al., 2020), Glycine max (59; Quach et al., 2015), Hordeum vulgare (23; Panahi et al., 2019), Manihot esculenta (51; He et al., 2019), Musa acuminate (44; Yan et al., 2019), Pinus tabuliformis (28; Guo et al., 2021), Prunus persica (24; Li et al., 2019), Ricinus communis (25: Wang et al., 2018). Sorghum bicolor (42: Malviva et al., 2016) and Vanilla planifolia (25; Arora et al., 2020). There are various reports which suggest about the role of NF-Y in various developmental processes such as embryogenesis (Lotan et al., 1998), nodule development (Combier et al., 2006), flowering (Chen et al., 2007), root elongation (Ballif et al., 2011), chlorophyll synthesis (Stephenson et al., 2011), etc. NF-YA1 in Arabidopsis has role in male gametogenesis (Mu et al., 2013). MtNF-YA1 showed higher gene expression during early stages of nodule development (Baudin et al., 2015). AtNF-YB9 (AtLEC1) gene was reported in regulating embryogenesis (West et al., 1994; Lotan et al., 1998). Overexpression of LEC1 increased seed oil formation in maize (Shen et al., 2010) while loss-of-function of LEC1 resulted in the formation of cotyledon (West et al., 1994). Overexpression of CgNF-YB9 affected the sucrose metabolism by decreasing sucrose and increasing fructose and glucose in Citrus grandis (Mai et al., 2019). Various studies regarding the role of NF-Y genes in mitigating stress has also been reported. ZmNF-YA3 was found to have dual role in flowering and drought and temperature tolerance in maize (Su et al., 2018). In wheat, TaN-F-YB3 help in tolerance to drought stress (Yang et al., 2017). Differential

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https://doi.org/10.1016/j.plgene.2022.100365

Received 1 November 2021; Received in revised form 20 May 2022; Accepted 27 May 2022 Available online 5 June 2022

2352-4073/© 2022 Published by Elsevier B.V.







Fig. 1. Multiple sequence alignment of NF-Y proteins of Dendrobium catenatum, Vanilla planifolia and Arabidopsis thaliana. a) NF-YA b) NF-YB c) NF-YC.

expression of *CsaNF-Y* genes was observed in drought and salt stress in *Cucumis sativus* (Chen et al., 2020). In *Picea wilsonii*, overexpression of *PwNF-YB3* increased drought and salt tolerance in *Arabidopsis* (Zhang et al., 2015). Ectopic expression of *GmNF-YA3* from soybean resulted in increased drought tolerance in *Arabidopsis* (Ni et al., 2013). Similarly, *CdtNF-YC1* from hybrid bermudagrass (*Cynodon dactylon* × *Cynodon transvaalensis*) increased drought and salt tolerance in *Paspalum vaginatum* (Wu et al., 2018).

Dendrobium catenatum is an economically important orchid species known for its medicinal and floricultural potential. But due to various man-made and environmental disturbances such as habitat destruction, unprecedented exploitation and climate change has pushed the orchid plants towards endangerment. Efforts are required to strengthen these growth and stress tolerance to facilitate development of robust plants. The sequenced genome of *Dendrobium catenatum* Lindl. (PRJNA262478; Zhang et al., 2016) offers valuable opportunity to identify and characterize gene specific to these molecular processes. *NF-Y* gene family is one such important candidate to study. Resultantly, a study was performed to identify and characterize *NF-Y* gene family in *D. catenatum*. This study aims to illuminate the role of *NF-Y* genes in growth and development and stress responses which in turn can pave way for future functional studies.

## 2. Materials and methods

## 2.1. Identification of putative NF-Y proteins in Dendrobium catenatum

Dendrobium catenatum NF-Y (DcNF-Y) sequences were identified by performing BLASTp searches using NF-Y sequences of Arabidopsis thaliana (Siefers et al., 2009) and Vanilla planifolia (Arora et al., 2020) in NCBI. The threshold cut-off was set at e-value of  $1 \times 10^{-10}$ . The sequences were confirmed by the presence of conserved domain i.e. smart00521 (CBF), pfam02045 (CBFB\_NFYA), pfam00808 (CBFD\_NFYB\_HMF) of cl23735 (H4) superfamily and cl30738 (HAP5) in Conserved Domain Database (CDD; https://www.ncbi.nlm.nih.gov/Stru cture/cdd/cdd.shtml) and pfam database (https://pfam.xfam.org). NCBI BLAST search was also conducted to identify orthologous proteins of NF-Y family in *V. planifolia*, *A. thaliana* and *D. catenatum*. The conserved domains of respective sub-units were identified and marked with MultAlin (http://multalin.toulouse.inra.fr/multalin/). Motif analysis was conducted using MEME (http://meme-suite.org/tools/meme) with motif width of 6–60; total of ten motifs with zero or one occurrence per sequence were predicted.

## 2.2. Phylogenetic analysis

The phylogenetic tree between NF-Y proteins of *V. planifolia*, *A. thaliana* and *D. catenatum* was constructed by neighbour-joining tree method using MEGA X with thousand bootstrap replications after aligning the sequences using MUSCLE (https://www.megasoftware.net).

## 2.3. Physico-chemical and interaction studies in DcNF-Y proteins

Physical and chemical features of proteins such as protein length, molecular weight (MW), aliphatic index (AI), isoelectric point (pI) and grand average of hydropathicity (GRAVY) values were calculated using PROTPARAM (https://web.expasy.org/protparam/). An interaction network of DcNF-Y protein was made with high confidence interaction score (0.7) using String (https://string-db.org/).

#### 2.4. Gene construction and promoter analysis

The gene architecture was constructed using CDS and gene sequences in GSDS (http://gsds.gao-lab.org/). Promoter region was predicted 1.5 kb upstream from the starting position of the gene and was subjected to PlantCARE database (http://bioinformatics.psb.ugent. be/webtools/plantcare/html/). The position of 12 cis-regulatory elements was visualized by MEME using any number of repition and 6–10 width size. The various cis-elements identified in three sub-families were subjected to Venn diagram and were categorised into four groups based on the developmental function associated with these elements (http://bioinformatics.psb.ugent.be/webtools/Venn/). .. .

(b)				
( )	DNA Bindin	ng NF-YA in	iteraction NF-	YC interaction
DcNF-YB1		PANGKIAKDAKETTQECYSEFISF	ITSEASEKCOREKRKTINGDDLLS	SAMATLG-FEEYIEPLKLYLQKYREMEGD
<b>VpNFYB2</b>	<b>VREODRFLPIANISRIMKKALI</b>	PSNGKIAKDAKETYQECYSEFISF	ITSEASDKCOREKRKTINGDDLL	ISHATLG-FEEYIEPLKLYLQKYREIEGD
DcNF-YB2	<b>VRELDRLLPIAFISRIMKKAL</b>	RPKGKIAKDAKETHQECYFEFISF	ITCEARDKCLREKRKKITEDDYL	CAMTTLDRFEDYIKPHRLYSQKYKEIEGD
DcNF-YB3	IVREQDRFLPIANISRIMKKALI	PPNGKIAKDAKETYQECYSEFISF	ITSEASDKCQREKRKTINGDDLL	IAMATLG-FEDYIEPLKLYLQKYREIEGD
ALNF-YB8	VREQDRFLPIANISRIMKRGL	PANGKIAKDAKEIYQECYSEFISF	YTSEASDKCQREKRKTINGDDLLI	IAMATLG-FEDYMEPLKYYLMRYREMEGD
ALNF-YB10	IVREQDRFLPIANISRIMKRGLI	PLNGKIAKDAKETMQECVSEFISF	YTSEASDKCQREKRKTINGDDLLI	IAMATLG-FEDYIDPLKYYLMRYREMEGD
ALNF-YB1	. VREQDRYLPIANISRIMKKALI	PPNGKIGKDAKDTYQECYSEFISF:	ITSEASDKCQKEKRKTYNGDDLLI	IAMATLG-FEDYLEPLKIYLARYREVFET
DcNF-YB6	SKEQDRFLPIANYSRIMKRSLI	PANAKISKEAKETYQECYSEFISF	YTGEASDKCQREKRKTINGDDLLI	IAMSTLG-FDSYYYPLRTYLNRYRESEGD
YPNFYB4	SKEQDRFLPIANYSRIMKRSLI	PANAKISKDAKETYQECYSEFISF	ITGEASDKCQREKRKTINGDDLL	IAMTTLG-FDSYVAPLKTYLGRYREAEGE
DcNF-YB7	TKENDRFLPIANYSRIMKKSLI	PSNAKISKEAKETYQECYSEFINF	YTGEASDKCQREKRKTINGDDLL	AMTTLG-FDSYVYPLKSYLSRYREGGGD
ALNF-YB7	NKEQDRFLPIANYGRIMKKYL	PGNGKISKDAKETYQECYSEFISF	YTGEASDKCQREKRKTINGDDII	AITTLG-FEDYVAPLKYYLCKYRDTEGE
DcNF-YB8	-REQDRFLPIANYSRIMKKALI	PANAKISKDAKETYQECYSEFISF	ITGEASDKCQREKRKTINGDDLL	AMTTLG-FEEYVEPLKIYLQRFREMEGE
DcNF-YBS	PREQDRLLPIANYSRIMKKALI	PANAKISKEAKETYQECYSEFISF	ITGEASDKCQREKRKTINGDDLL	AMTTLG-FEDYAEPLKLYLQKFRELEGD
YPNFYB:	PREQURLLPIHNYSRIMKKHLI	PHNHKISKUHKETYQECYSEFISF	11GEHSUKCQKEKRK11NGUULLI	HHHTLG-FEDYVEPLKLYLQKFRELEGD
HENF-YB2	PREQURFLP1HNVSR1HKKHLI	PHNHKISKUHKEIMUEUVSEFISF	Y I GEHSUKCUKEKRK I INGUULLI	HHIILG-FEUYVEPLKYYLURFREIEGE
HENF-YB:	TREUDRELPIHNYSRIMKKHLI	PHNHKISKUHKETYUECYSEFISF	1 I GEHSUKCUREKRK I INGUULLI	HHIILG-FEDYVEPLKYYLUKYREVEGE
UCNF-TB5	AKEADKLULTHNATKTUKKATI	PIHHKISUUHKEIIQEUVSEYISE	1 I SEHNERCUREURK I 1 THEDYL	HHSKLG-FUUYYEPLSYHLURYREHEGU
YPNF TB:	AKEANKLULTHNATKTUKKALI	PIHHKISUUHKEIIQEUVSETISE		
YPNF TBE		PIHHKISUUHKEIIQEUYSETISE		
		PHHHK15UUSKETIQECVCFVFF		
HENF-TB:		SHHKISUUHKEILQEUYSETISF		
		PPNGKIHKTHKUSYQEUYSEFIHF		
		SUBSTEREDAELWODCOCCELCE		
V-NEVD1			TTCENTNDCOVEDDVITNCENTI	
T T T T T T T T T T T T T T T T T T T	YKELUNFHFLYULUKLIKNIYI	CURVILLEUVILLACIA LELTOL	TISEUTOKCÓVEKKVATUGEDTAI	YLEDLU-FUCIICFLNLILNLIKENUNN
•		NE VR		
•		NF-YB		
•		NF-YB		
(2)	DNA	NF-YB		
(C)	DNA I	NF-YB		
(c)	DNA I	NF-YB Binding NF-YA interaction	NF-YB interaction	NF-YA interaction
(c)	DNA I	NF-YB Binding NF-YA interaction	NF-YB interaction	NF-YA interaction
(c)	DNA I	NF-YB Binding NF-YA interaction	NF-YB interaction	NF-YA interaction
(C) DCNF-YC1	DNA I	NF-YB Sinding NF-YA interaction	NF-YB interaction	VKLEDLRTAITSHSPTADFLLDCLPETSK
(C) DCNF-YC1 DCNF-YC5 DCNF-YC5	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPT POPGRCYHADQYREMEETTDFEKQREPL	NF-YB Binding NF-YA interaction RVKRIIKIDEDIKKVSSEALFL TIKKIDHADEDYDIVSNEAPU	NF-YB interaction ISLSTELFIEFHAEKAGNAA-ARKRRKI LRRACEHFILELTHKGLAHA-DQCCRR	VKLEDLRTAITBHSPTADFLLDCLPETSK IKKEDTARAVNETDYCOFL VPTITTEEP
(C) DCNF-YC1 DCNF-YC5 DCNF-YC5 DCNF-YC7	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPT PQPGRCYHADQYREMEETTDFEKQRIPL( PQHLQHYLANLYREIQQTTDFKHHSIPL) DOOL OHFADDQYREIDGTSDFKHHSIPL)	NF-YB Binding NF-YA interaction RVKRIIKIDEDIKKVSSEALFL TIKRIMIADEDYDIVSNEAPVL RXIKKINKADKDYRIIABCEAPY RXIKKINKADKDDYRIIABCEAPY RXIKKINKADKDDYRIIABCEAPY	NF-YB interaction ISLSTELFIEFMAEKAGNAA-ARKRRK LARACEMFILELTHKGHAHA-DQRCRR LTRACEMFIFELTRRAHAHA-EQMKRR	VKLEDLRTAITGHSPTADFLLDCLPETSK IKKEDIAAVLTKINHYDFLAESHKDIGG LQKNDTAAVLTKINHYDFLAESHKDIGG
(C) DCNF-YC1 DCNF-YC5 DCNF-YC7 DCNF-YC7 DCNF-YC8	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPTU PQPGRCYHADQYREMEETTDFEKQRZPL POHLOHVLANLYREIQQTTDFKHHSLPL JQQLQHFHADQYREIQTSDFKHSLPL JQQL-QHFHADQYREIQTSDFKHSLV	NF-YB Binding NF-YA interaction RYKRIIKNDEDIKKVSSEALFL TIKRIMMADEDYDIVSNEAPYL RIKKIMKADEDYRITABEAPTY RIKKIKADEDYRITABEAPYY RIKKIKADEDYRITABEAPYY	NF-YB interaction ISLSTELFIEFMAEKAGNAA-ARKRRKI LARACEMFILELTIKGAAHA-DQRCRR ILTRACEMFIFELTRRANAHA-EQNKRR FARACEMFILELTINSJAAHA-EENKRR FARACEMFILLELTINSJAAHA-EENKRR	VF-YA interaction VKLEDLRTAITGHSPTAOFLLDCLPETSK IKKEDIRAVLTKTMYDFLAFSHKDIGG LQKNDIRAVLTKTMYDFLAFSHKDIGG LQKNDIRAAITRTDVFOFLVDIVPREEG LQKNDIRAAITRTDVFOFLVDIVPREG
(C) DCNF-YC1 DCNF-YC5 DCNF-YC6 DCNF-YC7 DCNF-YC7 DCNF-YC7 DCNF-YC7	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPT PQPGRCYHADQYREHEETTDFEKQRIPL PQHLQHVLANLYREIQQTTOFKHHSIPL 1QQLQHFHADQYREIDGTSOFKHQSLPL 1QQLQHFHADQYREIEQTTOFKHHSLPL	NF-YB Sinding NF-YA interaction RYKRIIKINDEDIKKYSSEALFL TIKRINHADEDYRHIANEAPIY RIKKINKADEDYRHIANEAPYY RIKKIMKADEDYRHIANEAPYY RIKKIMKADEDY	NF-YB interaction ISLSTELFIEFHAEKAGNAA-ARKKRKI LARACEHFILELTIKGAAHA-DQCCRR LTRACEHFIFELTRRAHAHEQNKRR FRARCEHFILELTIRSNAHA-EENKKRR FARACEHFILDLTRSNAHA-EENKKRR	VKLEDLRTAITGHSPTADFLLDCLPETSK IKKEDITARVNETOYCOFLVPTITTEEP LQKNDTARAYLIKTNHYOFLAESHKDIGG LQKNDTARAYLIKTNHYOFLVDIVPREEG LQKNDTARAYLIRTDYFOFLVDIVPREEG LQKNDTARAYLIRTDYFOFLVDIVPREEG
(C) DCNF-YC1 DCNF-YC5 DCNF-YC5 DCNF-YC7 DCNF-YC7 DCNF-YC7 DCNF-YC3 DCNF-YC3	DNA I PYNQPSSDREETGEPGSDRGVLTPSFPT PQPGRCYHADQYREHEETTOFEKQRIPL PQHLQHVLANLYREIQQTTOFKNHSIPL IQQLQHFHADQYREIDQTSDFKNHSLPL IQQLQHFHADQYREIEQTTOFKNHSLPL IQQQLQIFHADQYREIEQTTOFKNHNLPL	NF-YB Binding NF-YA Interaction RYKRIIKMDEDIKKVSSEALFL TIKRIMHADEDVDIVSNEAPU RIKKIKADEDVRHIAREAPU RIKKIKADEDVRHIAREAPU RIKKIKADEDVRHIAREAPU RIKKIKADEDVRHIAREAPU RIKKIKADEDVRHIAREAPU RIKKIKADEDVRHIAREAPU RIKKIKADEDVRHIAREAPU RIKKIKADEDVRHIAREAPU	NF-YB interaction ISLSTELFIEFMAEKAGNAA-ARKRRK1 LRAACEMFILELTIKGAAHA-DQCCRR TRACEMFILELTIKGAAHA-EQNKRR FRARCEMFILELTIRSVAHA-EENKRR FRARCEMFILELTIRSVAHA-EENKRR FRARCEMFILELTIRSVAHA-EENKRR FRARCEMFILELTIRSVAHA-EENKRR	VKLEDLRTAITGHSPTADFLLDCLPETSK IKKEDIRARVETOYCOFLVPTITTEEP LQKNDIRARVITKTNHYDFLAESHKDIGG LQKNDIRARJITRTDVFOFLVDIVPREEG LQKNDIRARJITRTDVFOFLVDIVPREEG LQKNDIRARJITRTDVFOFLVDIVPREEG LQKNDIRARJITRTDVFOFLVDIVPREEG
(C) DCNF-YC1 DCNF-YC5 DCNF-YC6 DCNF-YC7 DCNF-YC7 DCNF-YC9 DCNF-YC19 DCNF-YC19	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPTI PQPGRCYHADQYREHEETTDFEKQRIPL( PQHLQHYLANLYREIQQTDFKHHSIPL) QQQLQHFADQYREIEQTSDFKHHSIPL) QQQLQHFADQYREIEQTTDFKHHSIPL) QQQLQHFADQYREIEQTTDFKHHSIPL) QQQLQHFADQYREIEQTTDFKHHSIPL) HQQLHHFHTYQRQEHEQAGDFKHQUPL) HQQULHFATYQRQEHEQAGDFKHQUPL)	NF-YB Binding NF-YA interaction RVKRIIKINDEDIKKVSSEALFL TIKRIMIADEDVDIVSNEAPVL RIKKIKADEDVRIIAREAPVW RIKKIKADEDVRIIAREAPVW RIKKIKADEDVRIIAREAPVW RIKKIKADEDVRIIAREAPVW RIKKIKADEDVRIIAREAPVW RIKKIKADEDVRIIAREAPVW RIKKIKADEDVRIIAREAPVW RIKKIKADEDVRIIAREAPVW RIKKIKADEDVRIIAREAPVW RIKKIKADEDVRIIAREAPVW RIKKIKADEDVRIIAREAPVW	NF-YB interaction ISLSTELFIEFMAEKAGNAA-ARKRRK LARACEMFILELTHKGHAHA-DQRCRR LTRACEMFILELTRRAHAHA-EQMKRR FRARCEMFILELTHRSHAHA-EEMKRR FRARCEMFILELTHRSHAHA-EEMKRR FRARCEMFILELTHRSHAHA-EEMKRR FRARCELFILELTHRSHAHA-EEMKRR	VKLEDLRTAITGHSPTADFLLDCLPETSK IKKEDIAAVLTKINHYDFLAESHKDIGG LQKNDIAAVLTKINHYDFLAESHKDIGG LQKNDIAAATLRTDYFOFLVDIYPREEG LQKNDIAAATLRTDYFOFLVDIYPREEG LQKNDIAAATLRTDYFOFLVDIYPREEG LQKNDIAAATLRTDYFOFLVDIYPREDI LQKNDIAAATLRTDYFOFLVDIYPREDI LQKND
(C) DCNF-YC1 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC6 DCNF-YC8 DCNF-YC9 DCNF-YC1 DCNF-YC1 DCNF-YC1 DCNF-YC1 DCNF-YC2 VeNFYC2	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPTI PQPGRCYHADQYREHEETTDFEKQRIPLI PQHLQHVHANLYREIQQTDFKHHSLPLI QQQLQHFHADQYREIDQTSDFKHQSLPLI QQQLQHFHADQYREIEQTTDFKHHSLPLI QQQLQIFHADQYREIEQTTDFKHHSLPLI QQQLQIFHADQYREIEQTTDFKHHSLPLI QQQLQIFHATYQRQEHEQAGDFKHHQLPLI QQQLLAFHSNQHHEIEQTTDFKHHSLPLI QQQLLAFHSNQHHEIEQTTDFKHHSLPLI	NF-YB Binding NF-YA interaction RYKRIIKHDEDIKKVSSEALFL TIKRIHHADEOVDIVSNEAPVL RIKKIHKADEOVRHIARAEPVW RIKKIHKADEOVRHIARAEPVU RIKKIHKADEOVRHIARAEPVU RIKKIHKADEOV	NF-YB interaction ISLSTELFIEFMAEKAGNAA-ARKRRKI LRRACEMFILELTHKGAAHA-DQRCRR ILTRACEMFIFELTRRANAHA-EQMKRR FARACEMFILELTHRSNAHA-EEMKRR FARACEMFILELTHRSNAHA-EEMKRR FARACEMFILELTRSNAHA-EEMKRR FARACEMFILELTRSNIHA-EEMKRR FARACEMFILELTRSNIHA-EEMKRR FARACEMFILELTRSNIHA-EEMKRR	VF-YA interaction VKLEDLRTAITGHSPTAOFLLDCLPETSK IKKEDIAAVLIKTIMYOFLAESHKDIGG LQKNDIAAAIIRTDVFOFLVDIVPREEG LQKNDIAAAIIRTDVFOFLVDIVPREEG LQKNDIAAAIIRTDVFOFLVDIVPREEG LQKNDIAAAIIRTDJFOFLVDIVPREDI LQKNDIAAAIIRTDJFOFLVDIVPREDI LQKNDIAAAIIRTDJFOFLVDIVPREDI LQKNDIAAAIIRTDJFOFLVDIVPREDI LQKNDIAAAIIRTDJFOFLVDIVPREDI LQKNDIAAAIIRTDJFOFLVDIVPREDI
(C) DCNF-YC1 DCNF-YC5 DCNF-YC5 DCNF-YC6 DCNF-YC9 DCNF-YC1 DCNF-YC11 DCNF-YC11 DCNF-YC12 VPNFYC2 VPNFYC2	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPTI POPGRCYHADQYREMEETTDFEKQRTPLI POHLQHYLANLYREIQQTTDFKNHSIPLI JQQLQHFHADQYREIGTSDFKNQSLPLI JQQLQHFHADQYREIEQTTDFKNHSLPLI JQQQLQIFAHDQYREIEQTTDFKNHSLPLI JQQQLLAFHTYQRQETGQTDFKHHSLPLI JQQQLLAFHTYQRQETEQTTDFKNHSLPLI JQQQLLAFHTYQRQETEQTDFKHHSLPLI JQQQLQFFHTYQRQETEQTNDFKHHSLPLI	NF-YB Binding NF-YA interaction RVKRIIKMDEDIKKVSSEALFL TIKRIMHADEOVDIVSNEAPVL RIKKIKADEOVRIIAAEAPVV RIKKIKADEOVRIIAAEAPVV RIKKIKADEOVRIIAAEAPVV RIKKIKADEOVRIISAEAPUI RIKKIKADEOVRIISAEAPVI RIKKIKADEOVRIISAEAPVI RIKKIKADEOVRIISAEAPVI RIKKIKADEOVRIISAEAPVI RIKKIKADEOVRIISAEAPVI RIKKIKADEOVRIISAEAPVI RIKKIKADEOVRIISAEAPVI RIKKIKADEOVRIISAEAPVI RIKKIKADEOVRIISAEAPVI	NF-YB interaction ISLSTELFIEFMAEKAGNAA-ARKKRKKI LRARCEMFILELTHKGAAHA-DQRCRR 'LTRACEMFIFELTRRANAHA-EQNKRR FRARCEMFILELTHRSNAHA-EENKRR 'FRARCEMFILELTHRSNAHA-EENKRR 'FRARCEMFILELTHRGNAHA-EENKRR 'FRARCEMFILELTIRSNIHA-EENKRR 'FRARCEMFILELTIRSNIHA-EENKRR 'FRARCEMFILELTIRSNIHA-EENKRR 'FRARCEMFILELTIRSNIHA-EENKRR	NF-YA interaction YKLEDLRTAITGHSPTAOFLLDCLPETSK IKKEDIRARUETDYCOFLVPTITTEEP LQKNDIRARUETKTNHYDFLAESHKDIGG LQKNDIRARITRTDYFOFLVDIVPREEG LQKNDIRARITRTDYFOFLVDIVPREEG LQKNDIRARITRTDFFUVDIVPREEG LQKNDIRARITRTDIFOFLVDIVPRDEL LQKNDIRARITRTDIFOFLVDIVPRDEL LQKNDIRARITRTDIFOFLVDIVPRDEL LQKNDIRARITRTDIFOFLVDIVPRDEL LQKNDIRARITRTDIFOFLVDIVPRDEL
(C) DCNF-YC1 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC7 DCNF-YC7 DCNF-YC1 DCNF-YC12 VPNFYC2 VPNFYC2 RENF-YC1	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPTI PQPGRCYHADQYREHEETTDFEKQRIPLI PQHLQHVLANUYREIQTTOFKHHSLPLI QQQLQHFHADQYREIDGTSDFKHHSLPLI QQQLQIFHADQYREIEQTTDFKHHSLPLI QQQLQIFHADQYREIEQTTDFKHHSLPLI QQQLQIFHADQYREIEQTTDFKHHSLPLI QQQLQFHTYQRQEIEQWNDFKHHQLPLI QQQLQFHTYQRQEIEQWNDFKHHQLPLI QQQLQFHTYQRQEIEQWNDFKHHQLPLI	NF-YB Sinding NF-YA Interaction RVKRIIKMDEDIKKVSSEALFL TIKRIMMADEDVDIVSNEAPUL RIKKIMKADEDVRHIAREAPUX RIKKIMKADEDVRHIAREAPUX RIKKIMKADEDVRHIAREAPUX RIKKIMKADEDVRHISREAPUI RIKKIMKADEDV	NF-YB interaction ISLSTELFIEFMAEKAGNAA-ARKRRK1 LRAACEMFILELTIKGAAHA-DQQCCRT LTROCEMFILELTIKGAAHA-EENKRR FRAACEMFILELTIRSVAHA-EENKRR FRARCEMFILELTIRSVAHA-EENKRR FARACEMFILELTIRSVAHA-EENKRR FRARCEMFILELTIRSVIHT-EENKRR FRAACEMFILELTIRSVIHT-EENKRR FRAACEMFILELTIRSVIHT-EENKRR FARACELFILELTIRSVIHT-EENKRR FARACELFILELTIRSVIHT-EENKRR	VKLEDLRTAITGHSPTADFLLDCLPETSK IKKEDIRARVIKTNHYDFLAESHKDIGG LQKNDIRARJIRTDVFDFLVDIVPREEG LQKNDIRARJIRTDVFDFLVDIVPREEG LQKNDIRARJIRTDVFDFLVDIVPREEG LQKNDIRARJIRTDVFDFLVDIVPREDI LQKNDIRARJIRTDIFDFLVDIVPREDI LQKNDIRARJIRTDIFDFLVDIVPRDEI LQKNDIRARJIRTDIFDFLVDIVPRDEI LQKND
(C) DCNF-YC1 DCNF-YC5 DCNF-YC6 DCNF-YC7 DCNF-YC7 DCNF-YC1 DCNF-YC1 DCNF-YC12 VPNFYC2 RLNF-YC1 ALNF-YC3 OCNF-YC1 ALNF-YC3 OCNF-YC1	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPTI PQPGRCYHADQYREHEETTDFEKQRIPL( PQHLQHYLANLYREIQQTDFKHHSLPL1 QQLQHFADQYREIEQTTDFKHHSLPL1 QQLQLHAFADQYREIEQTTDFKHHSLPL1 QQQLQHFADQYREIEQTTDFKHHSLPL1 QQQLQHFANQYREIEQTTDFKHHSLPL1 QQQLQHFKNQHEIEQTTDFKHHSLPL1 QQQLQFFKNQHSEIEQTTDFKHHSLPL1 QQQLQFFHYQRQEIEQYNDFKHHQLPL1 QQQLQFFHYQRQEIEQYNDFKHHQLPL1 AQQLQAFFHYQREETEXTDFKHHSLPL1 AQQLQAFFHYQREETEXTDFKHHSLPL1 AQQLQAFFHYQREETEXTDFKHHSLPL1	NF-YB Binding NF-YA interaction RVKRIIKINDEDU	NF-YB interaction ISLSTELFIEFHAEKAGNAA-ARKRRK1 LARACEHFILELTHKGJAHA-DQRCRR LTRACEHFILELTRRAJAHA-EQMKRR1 FRARCEHFILELTHRSJAHA-EEMKRR1 FRARCEHFILELTHRSJAHA-EEMKRR1 FRARCEHFILELTRSJHA-EEMKRR1 FRARCELFILELTRSJHA-EEMKRR1 FRARCELFILELTRSJHA-EEMKRR1 FRARCELFILELTRSJHA-EEMKRR1 FRARCELFILELTRSJHA-EEMKRR1 FRARCELFILELTRSJHA-EEMKRR1 FRARCELFILELTRSJHA-EEMKRR1 FRARCELFILELTRSJHA-EEMKRR1 FRARCELFILELTRSJHA-EEMKRR1 FRARCELFILELTRSJHA-EEMKRR1 FRARCELFILELTRSJHA-EEMKRR1 FRARCELFILELTRSJHA	NF-YA interaction   VKLEDL ITARY NETDYCOFL UPTITTEEP   LQKND ITARY NETDYCOFL UPTITTEEP   LQKND ITARY IKTINTOFLAESHKDIGG   LQKND IARATIRTOY FOFL VDIVPREEG   LQKND IARATIRTOY FOFL VDIVPREEG   LQKND IARATIRTOY FOFL VDIVPREEG   LQKND IARATIRTOY FOFL VDIVPREEG   LQKND IARATIRTOFFOFL VDIVPREEG   LQKND IARATIRTOFFOFL VDIVPREED
(C) DCNF-YC1 DCNF-YC5 DCNF-YC5 DCNF-YC7 DCNF-YC7 DCNF-YC1 DCNF-YC1 DCNF-YC1 DCNF-YC1 ALNF-YC3 ALNF-YC3 ALNF-YC3 ALNF-YC3 ALNF-YC3	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPTI PQPGRCYHADQYREHEETTDFEKQRIPLI PQHLQHYLANLYREIQQTDFKHHSLPLI QQQLQHFHADQYREIDQTSDFKHGSLPLI QQQLQHFHADQYREIEQTTDFKHHSLPLI QQQLQHFHADQYREIEQTTDFKHHSLPLI QQQLQHFHYQRQEHEQAGDFKHHSLPLI QQQLQHFHYQRQEIEQYNDFKHHSLPLI QQQLQHFHYQRQEIEQYNDFKHHSLPLI QQQLQHFHYQRQEIEQYNDFKHHSLPLI QQQLQFFHTQRREIEXTTDFKHHSLPLI TQQLQSFHETQFKEIEKTTDFKHHSLPLI TQQLQSFHETQFKEIEKTTDFKHHSLPLI	NF-YB Binding NF-YA interaction RYKRIIKHDEDI	NF-YB interaction ISLSTELFIEFMREKAGNAR-ARKRRK LARACEMFILELTHKGJAHA-DQRCRT UTRACEMFIFELTRRAHAHA-EQMKRT FARACEMFILELTHRSJAHA-EEMKRRT FARACEMFILELTHRSJAHA-EEMKRRT FARACEMFILELTRSJAHA-EEMKRRT FARACELFILELTRSJIHT-EEMKRRT FARACELFILELTRSJIHT-EEMKRRT FARACELFILELTRSJIHT-EEMKRRT FARACELFILELTRSJIHT-EEMKRRT FARACELFILELTRSJIHT-EEMKRRT FARACELFILELTRSJIHT-EEMKRRT FARACELFILELTRSJIHT-EEMKRRT FARACELFILELTLRSJIHT-EEMKRRT FARACELFILELTLRSJIHT-EEMKRRT FARACELFILELTLRSJIHT-EEMKRRT FARACELFILELTLRSJIHT-EEMKRRT	NF-YA interaction   VKLEDLRTAITGHSPTAOFLLDCLPETSK   IKKEDIAAVLIKINHYDFLAESHKDIGG   LQKNDIAAVLIKINHYDFLAESHKDIGG   LQKNDIAAATIRTDYFOFLVDIVPREEG   LQKNDIAAATIRTDYFOFLVDIVPREEG   LQKNDIAAATIRTDYFOFLVDIVPREEG   LQKND
(C) DCNF-YC1 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC1 DCNF-YC1 DCNF-YC1 DCNF-YC1 DCNF-YC1 DCNF-YC2 RLNF-YC4 RLNF-YC3 RLNF-YC3 RLNF-YC3 RLNF-YC3 RLNF-YC3	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPTI PQPGRCYHADQYREMEETTDFEKQRZPLI PQHLQHYHADQYREIDQTSDFKNHSLPLI QQQLQHFHADQYREIEQTTDFKNHSLPLI QQQLQHFHADQYREIEQTTDFKNHSLPLI QQQLQIFHADQYREIEQTTDFKNHSLPLI QQQLQIFHADQYREIEQTTDFKNHSLPLI QQQLQFFHTYQRQEIEQYNDFKNHQLPLI QQQLQHFATYQRQEIEQYNDFKNHQLPLI QQQLQHFATYQRQEIEQYNDFKNHQLPLI QQQLQHFATYQRQEIEQYNDFKNHQLPLI QQQLQHFATYQRQEIEQYNDFKNHQLPLI QQQLQHFATYQRQEIEQYNDFKNHQLPLI TQQLQSFHETQFKEIEKTTDFKNHSLPLI TQQLQSFHETQFKEIEKTTDFKNHSLPLI QQQLQHFATYQRQEIEQYNDFKNHQLPLI TQQLQSFHETQFKEIEKTTDFKNHSLPLI	NF-YB Binding NF-YA Interaction RYKRIIKHDEDIKKVSSEALFL TIKRIHHADEDYDIVSNEAPVL RIKKIHKADEDYRHIAREAPVY RIKKIHKADEDYRHIAREAPVY RIKKIHKADEDY	NF-YB interaction ISLSTELFIEFMAEKAGNAA-ARKKRKI LRARCEHFILELTIKGAAHA-DQQCRR FARACEHFILELTIKGAAHA-EQNKRR FARACEHFILELTIRSNAHA-EENKRR FARACEHFILELTIRSNAHA-EENKRR FARACEHFILELTIRSNAHA-EENKRR FARACEHFILELTIRSNAHA-EENKRR FARACEHFILELTIRSNAHA-EENKRR FARACEHFILELTIRSNAHA-EENKRR FARACEHFILELTIRSNAHA-EENKRR FARACEHFILELTIRSNAHA-EENKRR FARACEHFILELTIRSNAHA-EENKRR FARACEHFILELTIRSNAHA-EENKRR FARACEHFILELTIRSNAHA-EENKRR FARACEHFILELTIRSNAHA-EENKRR FARACEHFILELTIRSNAHA-EENKRR FARACEHFILELTIRSNAHA-EENKRR	NF-YA interaction   YKLEDLRTAITGHSPTAOFLLDCLPETSK   IKKEDIARAVLIKTIMIYOFLAPSITTEEP   LQKNDIARATIRTDYFOFLVDIVPREEG   LQKNDIARATIRTDYFOFLVDIVPREEG   LQKNDIARATIRTDYFOFLVDIVPREEG   LQKND
(C) DCNF-YC1 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC7 DCNF-YC7 DCNF-YC7 DCNF-YC1 DCNF-YC1 DCNF-YC1 DCNF-YC2 VPNFYC2 ALNF-YC4 ALNF-YC3 ALNF-YC2 VPNFYC3 ALNF-YC8	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPTI PQPGRCYHADQYREHEETTDFEKQRIPLI PQHLQHVLANUYREIQTTDFKHHSLPLI QQQLQHFANDQYREIDGTSDFKHHSLPLI QQQLQIFHADQYREIEQTTDFKHHSLPLI QQQLQIFHADQYREIEQTTDFKHHSLPLI QQQLQIFHADQYREIEQTTDFKHHSLPLI QQQLQIFHADQYREIEQTTDFKHHSLPLI QQQLQIFHATYQRQEIEQVNDFKHHQLPLI QQQLQFFATYQRQEIEQVNDFKHHQLPLI QQQLQFFATYQRQEIEQVNDFKHHQLPLI QQQLQFFATYQRQEIEQVNDFKHHQLPLI QQQLQFFATYQRQEIEQVNDFKHHQLPLI QQQLQFFATYQRQEIEQVNDFKHHQLPLI QQQLQFFATYQRQEIEQVNDFKHHQLPLI QQQLQFFATYQRQEIEQVNDFKHHQLPLI QQQLQFFATYQRQEIEQVNDFKHHQLPLI QQQLQFFATYQRQEIEQVNDFKHHQLPLI QQQLQFFATYQRQEIEQVNDFKHHQLPLI QQQLQFFATYQRQEIEQVNDFKHHQLPLI QQQLQFFATYQRQEIEQVNDFKHHQLPLI QQQLQFFATYQRQEIEQVNDFKHHQLPLI QQQLQFFATYQRQEIEQVNDFKHHQLPLI QQQLQFFANDY	NF-YB Binding NF-YA Interaction RYKRIIKMDEDIKKVSSEALFL TIKRIMHADEDVDIVSNEAPUL RIKKIMKADEDVRHIAREAPIY RIKKIMKADEDVRHIAREAPYY RIKKIMKADEDVRHIAREAPYY RIKKIMKADEDVRHISREAPYI RIKKIMKADEDVRHISREAPYI RIKKIMKADEDV	NF-YB interaction ISLSTELFIEFMAEKAGNAA-ARKRRK1 LRAACEHFILELTHKGAAHA-DQQCRR TRACEHFILELTHKGAAHA-EQNKRR FRARCEHFILELTHRSAAHA-EENKRR FRARCEHFILELTHRSAAHA-EENKRR FRARCEHFILELTRSAHAA-EENKRR FRARCEHFILELTRSAHAA-EENKRR FRARCEHFILELTRSAHAA-EENKRR FRARCEHFILELTRSAHA-EENKRR FRARCEHFILELTRSAHA-EENKRR FRARCEHFILELTRSAHA-EENKRR FRARCEHFILELTRSAHA-EENKRR FRARCEHFILELTRSAHA-EENKRR FRARCEHFILELTRSAHA-EENKRR FRARCEHFILELTRSAHA-EENKRR FRARCEHFILELTRSAHA-EENKRR FRARCEHFILELTRSAHA-EENKRR FRARCEHFILELTRSAHAA-EENKRR FRARCEHFILELTRSAHAA-EENKRR FRARCEHFILELTRSAHAA-EENKRR FSARCEHFILELTRSAHAA-EENKRR FSARCEHFILELTRSAHAA-EENKRR	VK-YA interaction VKLEDLRTAITIGHSPTADFLLDCLPETSK IKKEDIRARVIETOYCOFLVPTITTEEP LQKNDIRARVIETOYFOFLVDIVPREEG LQKNDIRARITRTDVFOFLVDIVPREEG LQKNDIRARITRTDVFOFLVDIVPREEG LQKNDIRARITRTDVFOFLVDIVPREEG LQKNDIRARITRTDIFOFLVDIVPREDI LQKNDIRARITRTDIFOFLVDIVPREDI LQKNDIRARITRTDIFOFLVDIVPREDI LQKNDIRARITRTDIFOFLVDIVPREDI LQKNDIRARITRTDIFOFLVDIVPREDI LQKNDIRARITRTDIFOFLVDIVPREDI LQKNDIRARITRTDIFOFLVDIVPREDI LQKNDIRARITRTDIFOFLVDIVPREDI LQKNDIRARITRTDIFOFLVDIVPREDI LQKNDIRARITRTDIFOFLVDIVPREDI LQKNDIRARITRTDIFOFLVDIVPREDI LQKNDIRARITRTDIFOFLVDIVPREDI LQKNDIRARITRTDIFOFLVDIVPREDI LQKNDIRARITRTDIFOFLUDIPREVI LQKND
(C) DCNF-YC1 DCNF-YC5 DCNF-YC6 DCNF-YC7 DCNF-YC7 DCNF-YC7 DCNF-YC1 DCNF-YC1 DCNF-YC1 DCNF-YC2 PUNFYC2 PUNFYC2 RLNF-YC3 RLNF-YC3 RLNF-YC3 RLNF-YC5	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPTI PQPGRCYHADQYREHEETTDFEKQRIPL( PQHLQHYLANLYREIQTTDFKHHSIPL) QQQLQHFADQYREIEQTTDFKHHSIPL) QQQLQHFADQYREIEQTTDFKHHSIPL) QQQLQHFADQYREIEQTTDFKHHSIPL) QQQLQHFADQYREIEQTTDFKHHSIPL) QQQLQHFANQQYREIEQTTDFKHHSIPL) QQQLQHFATYQRQEIEQYNDFKHHQIPL) QQQLQFFATYQRQEIEQYNDFKHHQIPL) QQQLQFFATYQRQEIEQYNDFKHHQIPL) AQQLQAFHENQFKEIEKTTDFKHHSIPL) TQQLQSFHETQFKEIEKTTDFKHHSIPL) TQQQLQFFANQFKEIEKTTDFKHHSIPL) TQQQLQFFANQFKEIEKTTDFKHHSIPL) TQQQLQFFANQFKEIEKTTDFKHHSIPL) TQQQLQFFANQQFITTDFKHHSIPL) TQQQLQFFANQFKEIEKTTDFKHHSIPL) TQQQLQFFANQCFKEIEKTTDFKHHSIPL) TQQLQSFHETQFKEIEKTTDFKHHSIPL) TQQLQFFANQCFICHTFFKHHNLPI TQQLQFFANQCFICHTFFKHHNLPI TQQLQFFANQCFICHTFFKHHNLPI TQQLQFFANQCFICHTFFKHHNLPI TQQLQFFANQCFICHTFFKHHNLPI TQQLQFFANQCFICHTFFKHHNLPI TQQLQFFANQCFICHTFFKHHNLPI TQQLQFFANQCFICHTFFKHHNLPI TQQLQFFANQCFICHTFFKHHLPI TQQLQFFANQCFICHTFFKHHLPI TQQLQFFANQCFICHTFFKHHLPI TQQLQFFANQCFICHTFFKHHLPI TQQLQFFANQCFICHTFFTFKHHLPI TQQLQFFANQCFICHTFFKHHLPI TQQLQFFANQCFICHTFFKHHLPI TQQLQFFANQCFICHTFFKHHLPI TQQLQFFANQCFICHTFFKHHLPI TQQLQFFANQCFICHTFFKHHLPI TQQLQFFANQCFICHTFFKHHLPI TQQLQFFANQCFICHTFFKHHLPI TQQLQFFANQCFICHTFFKHLFFT TQQLQFFANQCFICHTFFKHLFFT TQQL	NF-YB Binding NF-YA interaction RVKRIIKINDEDIKKVSSEALFL TIKRIMIADEDVDIVSNEAPVL RIKKIKADEDVRIIARCAPVU RIKKIKADEDVRIIARCAPVU RIKKIKADEDVRIIARCAPVU RIKKIKADEDVRIISRCAPVI RIKKIKADEDVRIISRCAPVI RIKKIKADEDV	NF-YB interaction ISLSTELFIEFHAEKAGNAA-ARKRRK1 LARACEHFILELTHKGHAHA-DQRCRR1 LTRACEHFILELTHRSHAHA-EQHKRR1 FARACEHFILELTHRSHAHA-EEMKRR1 FARACEHFILELTHRSHAHA-EEMKRR1 FARACEHFILELTRSHIHA-EEMKRR1 FARACEHFILELTRSHIHA-EEMKRR1 FARACEHFILELTRSHIHA-EEMKRR1 FARACEHFILELTRSHIHA-EEMKRR1 FARACEHFILELTRSHIHA-EEMKRR1 FARACEHFILELTRSHIHA-EEMKRR1 FARACEHFILELTRSHIHA-EEMKRR1 FARACEHFILELTRSHIHA-EEMKRR1 FARACEHFILELTRSHIHA-EEMKRR1 FARACEHFILELTRSHIHA-EEMKRR1 FARACEHFILELTRSHIHA-EEMKRR1 FARACEHFILELTRSHIHA-EEMKRR1 FARACEHFILELTRSHIHA-EEMKRR1 FSRACEHFILELTRSHIHA-EEMKRR1 SKACEHFILELTRSHIHA-EEMKRR1 SKACEHFILETRSHIHA-EESKRR1 LSKACEHFINDTMRSHLHA-QESKRY1	NF-YA interaction   VKLEDL TIARY NETDYCOFL VPTITTEEP   LQKND TIARY NETDYCOFL VPTITTEEP   LQKND TARAY TRIVY OFL VDIVPREEG   LQKND TARAT RTOY OFL VDIVPREEG   LQKND TARAT RTOY OFL VDIVPREEG   LQKND TARAT RTOIF OFL VDIVPREED   LQKND TARAT SROIF OFL LOUTPREED   LQKND TARAT SROIF OFL LOUTPREED   LQKSN
(C) DCNF-YC1 DCNF-YC5 DCNF-YC5 DCNF-YC6 DCNF-YC7 DCNF-YC19 DCNF-YC19 DCNF-YC11 DCNF-YC14 DCNF-YC14 ALNF-YC14 ALNF-YC2 ALNF-YC3 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 ALNF-YC5 AL	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPTI PQPGRCYHADQYREHEETTDFEKQRIPLI PQHLQMYLANLYREIQATTDFKNHSIPLI QQQLQHFHADQYREIDQTSDFKHHSIPLI QQQLQHFHADQYREIEQTTDFKHHSIPLI QQQLQHFHADQYREIEQTTDFKHHSIPLI QQQLQHFHADQYREIEQTTDFKHHSIPLI QQQLQHFHYQRQEHEQAGDFKHHQLPLI QQQLQHFHYQRQEHEQYNDFKHHSIPLI QQQLQHFHYQRQEIEQYNDFKHHQLPLI QQQLQHFHADQYREIEQTTDFKHHSIPLI TQQLQSFHETQFKEIEKTTDFKHHSIPLI TQQLQSFHETQFKEIEKTTDFKHHSIPLI TQQLQSFHETQFKEIEKTTDFKHHSIPLI TQQLQFFHADQQEIRATTDFKHHSIPLI TQQLQSFHETQFKEIEKTTDFKHHSIPLI TQQLQSFHETQFKEIEKTTDFKHHSIPLI TQQLQFFHADQQEIRATTDFKHHSIPLI TQQLQFFHADQQEIRATTDFKHHFPI SFQHRNYHIROHGARTUVKHHAPLI DQDNNY	NF-YB Binding NF-YA interaction RVKRIIKMDEDIKKVSSEALFL TIKRIMMADEDVDIYSMEAPVL RIKKIMADEDVRHIARGAPVY RIKKIMADEDV	NF-YB interaction ISLSTELFIEFMREKAGNAR-ARKRRKI LARACEHFILELTHKGHAHA-DQRCRRI LTRACEHFILELTRRAHAHA-EQMKRRI FARACEHFILELTRSAHAHA-EUMKRRI FARACEHFILELTHRSAHAHA-EEMKRRI FARACEHFILELTRSAHAHA-EEMKRRI FARACEHFILELTRSAHAHA-EEMKRRI FAKACELFILELTRSAHAH-EEMKRRI FAKACELFILELTRSAHAH-EEMKRRI FAKACELFILELTRSAHAH-EEMKRRI FARACEHFILELTRSAHAH-EEMKRRI FARACEHFILELTRSAHAH-EEMKRRI FARACEHFILELTRSAHAH-EEMKRRI FARACEHFILELTRSAHAH-EEMKRRI FARACEHFILELTRSAHAH-EEMKRRI FRARCEHFILELTRSAHAH-EEMKRRI FRARCEHFILELTRSAHAH-EEMKRRI FRARCEHFILELTRSAHAH-EEMKRRI FRARCEHFILELTRSAHAH-EEMKRRI FRARCEHFILELTRSAHAH-EEMKRRI SKACEHFILELTRSAHAH-EEMKRRI SKACEHFILELTRSAHAHA-EEMKRRI SKACEHFILELTRSAHAHA-EEMKRRI SKACEHFILELTRSAHAHA-EEMKRRI SKACEHFILELTRSAHAHA-EEMKRRI SKACEHFILELTRSAHAHA-EEMKRRI SKACEHFILELTRSAHAHA-EEMKRRI SKACEHFILELTRSAHAHA-EEMKRRI SKACEHFILELTRSAHAHA-EEMKRRI SKACEHFILELTRSAHAHA-EEMKRRI SKACEHFILELTRSAHAHA-EEMKRRI SKACEHFILELTRSAHAHA-EEMKRRI SKACEHFILELTRSAHAHA	NF-YA interaction   VKLEDL RTAITIGHSPTAOFILDCLPETSK   IKKED IARAVIETDYCOFLVPTITTEP   LQKND IARAVIETDYCOFLVPTITTEP   LQKND IARAVIETDYFOFLVDIVPREG   LQKND IARATIRTDYFOFLVDIVPREG   LQKND IARATIRTOFOFLVDIVPREG   LQKND IARATIRTOFOFLVDIVPREG   LQKND IARATIRTOFOFLVDIVPREG   LQKND IARATIRTOFOFLVDIVPRED   LQKND IARATIRTOFOFLVDIVPREP   LQKND
(C) DCNF-YC1 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC1 DCNF-YC1 DCNF-YC1 DCNF-YC1 DCNF-YC1 DCNF-YC1 ALNF-YC3 ALNF-YC3 ALNF-YC3 ALNF-YC5 ALNF-YC7 ALNF-YC7 ALNF-YC1 DCNF-YC10	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPTI PQPGRCYHADQYREHEETTDFEKQRZPLI PQHLQHVLANLYREIQQTDFKHISLPLI QQQLQHFHADQYREIDQTSDFKHISLPLI QQQLQHFHADQYREIEQTTDFKHISLPLI QQQLQHFHADQYREIEQTTDFKHISLPLI QQQLQHFHADQYREIEQTTDFKHISLPLI QQQLQHFHADQYREIEQTTDFKHISLPLI QQQLQHFHATYQRQEIEQYNDFKHISLPLI QQQLQHFHTYQRQEIEQYNDFKHISLPLI QQQLQHFHTYQRQEIEQYNDFKHISLPLI QQQLQHFHTYQRQEIEQYNDFKHISLPLI TQQLQSFHETQFKEIEKTTDFKHISLPLI TQQLQFHANQLQEITTDFKHISLPLI TQQLQFFANQLQEITTDFKHISLPLI TQQLQFFANQLQEITTDFKHISLPLI TQQLQFFANQLQEIFHTTFKHISLPLI TQQLQFFANQLQEIFTTDFKHISLPLI TQQLQFFANQLQEIFTTDFKHISLPLI TQQLQFFANQLQEIFTTDFKHISLPLI TQQLQFFANQLQEIFTTDFKHISLPLI TQQLQFFANQLQEIFTTDFKHISLPLI TQQLQFFANQLQEIFTTDFKHISLPLI TQQLQFFANQLQEIFTTDFKHISLPLI TQQLQFFANQLQEIFTTDFKHISLPLI TQQLQFFANQLQEIFTTDFKHISLPLI TQQLQFFANQLQEIFTTDFKHISLPLI TQQLQFFANQLQIFFANGUEIFTTDFKHISLPLI TQQLQFFANQLQIFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQHFANQLQIFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHISLPLI TQQLQFFANGUEIFTTDFKHI TQQLQFFANGUEIFTTDFKHI TQQLQFFANGUEIFTTDFKHI TQQLQFFANGUEIFTTDFKHI TQQLQFFANGUEIFTTDFKHI TQQLQFFANGUEIFTTDFKHI TQQLQFFANGUEIFTTDFKHI TQQLQFFANGUEIFTTDFKHI TQQLQFFANGUEIFTTDFKHI TQQLQFFANGUEIFTTDFKHI TQQQ	NF-YB Binding NF-YA Interaction RYKRIIKHDEDIKKVSSEALFL TIKRIMHADEDVDIVSNEAPVL RIKKIMKADEDVRTIARAEAPVL RIKKIMKADEDV	NF-YB interaction ISLSTELFIEFMAEKAGNAA-ARKKRKI LRARCEHFILELTIKGAAHA-DQQCRR TRARCEHFILELTIKGAAHA-EQNKRR FARACEHFILELTIRSVAHA-EENKRR FARACEHFILELTIRSVAHA-EENKRR FARACEHFILELTIRSVAHA-EENKRR FARACEHFILELTIRSVAHA-EENKRR FARACEHFILELTIRSVAHA-EENKRR FARACEHFILELTIRSVAHA-EENKRR FARACEHFILELTIRSVAHA-EENKRR FARACEHFILELTIRSVAHA-EENKRR FARACEHFILELTIRSVAHA-EENKRR FARACEHFILELTIRSVAHA-EENKRR FARACEHFILELTIRSVAHA-EENKRR FARACEHFILELTIRSVAHA-EENKRR FARACEHFILELTIRSVAHA-EENKRR FARACEHFILELTIRSVAHA-EENKRR FARACEHFILELTIRSVAHA-EENKRR SKACEHFILELTIRSVAHA-EENKRR LSKACEHFILELTIRSVAHA-EENKRR LSKACEHFILELTIRSVAHA-EENKRR SKACEHFILELTIRSVAHA-EENKRR SKACEHFILELTIRSVAHA-EENKRR SKACEHFILELTIRSVAHA-EENKRR SKACEHFILELTIRSVAHA-EENKRR	VKLEDLRTAITGHSPTAOFLLDCLPETSK IKKEDIAAVLIKINHYDFLAESHKDIGG LQKNDIAAVLIKINHYDFLAESHKDIGG LQKNDIAAAITRIDYFOFLVDIVPREEG LQKNDIAAAITRIDYFOFLVDIVPREEG LQKNDIAAAITRIDYFOFLVDIVPREEG LQKNDIAAAITRIDIFOFLVDIVPREEG LQKNDIAAAITRIDIFOFLVDIVPREEI LQKNDIAAAITRIDIFOFLVDIVPREEI LQKNDIAAAITRIDIFOFLVDIVPREEI LQKNDIAAAITRIDIFOFLVDIVPREEI LQKNDIAAAITRIDIFOFLVDIVPREEI LQKNDIAAAITRIDIFOFLVDIVPREEI LQKNDIAAAITRIDIFOFLVDIVPREEI LQKND
(C) DCNF-YC1 DCNF-YC5 DCNF-YC5 DCNF-YC7 DCNF-YC9 DCNF-YC9 DCNF-YC19 DCNF-YC12 VPNFYC1 DCNF-YC12 VPNFYC2 VPNFYC2 ALNF-YC4 ALNF-YC4 ALNF-YC5 ALNF-YC5 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 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FSRACEHFILELTRSAHH-EENKRR FSRACEHFILELTRSAHH-EENKRR FSRACEHFILELTRSAHH-EENKRR FSRACEHFILELTRSAHH-EENKRR FSRACEHFILELTRSAHA SKACEHFIND TRSAHA SKACEHFIND TRSAHA SKACEHFIND TRSAHA SKACEHFIND TRSAHA SKACEHFIND TRSAHA SKACEHFIND TRSAHA SKACEHFIND TRSAHA SKACEHFIND TRSAHA SKACEHFIND TRSAHA SKACEHFIND TRSAHA SKACEHFIND TRSAHA SKACEHFIND TRSAHA SKACEHFIND TRSAHA SKACEHFIND TRSAHA SKACEHFIND TRSAHA SKACEHFIND TRSAKA SKACEHFIND TRSAHA SKACEHFIND SKACEHFIND SKACEHFIND SKACEHFIND SKACEHFIND SKACEHFIND SKACEHFIND SKACEHFIND SKACEHFIND SKACEHFIND SKACEHFIND SKACEHFIND SKACEHFIND SKACEHFIND SKACEHFIND SKACEHFIND SKACEHFIND SKACEHFIND SKACEHFIND SKACH SKACH SKACEHFIND SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH SKACH	VKLEDLRTAITIGHSPTADFLLDCLPETSK IKKEDIRARVIETOYCOFLVPTITTEEP LQKNDIRARVIETOYTOFLABSHKDIGG LQKNDIRARTIRTDYFOFLVDIVPREEG LQKNDIRARTIRTDYFOFLVDIVPREEG LQKNDIRARTIRTDYFOFLVDIVPREEG LQKNDIRARTIRTDIFOFLVDIVPREDI LQKNDIRARTIRTDIFOFLVDIVPREDI LQKND
(C) DCNF-YC1 DCNF-YC5 DCNF-YC6 DCNF-YC7 DCNF-YC7 DCNF-YC7 DCNF-YC1 DCNF-YC1 DCNF-YC1 DCNF-YC2 PUNFYC2 PUNFYC2 PUNFYC3 RLNF-YC3 RLNF-YC3 RLNF-YC5 RLNF-YC5 RLNF-YC6 DCNF-YC2 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF-YC10 DCNF	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPTI PQPGRCYHADQYREHEETTDFEKQRIPL( PQHLQHYLANLYREIQTTDFKHHSLPLI QQQLQHFADQYREIEQTTDFKHHSLPLI QQQLQHFADQYREIEQTTDFKHHSLPLI QQQLQHFADQYREIEQTTDFKHHSLPLI QQQLQHFADQYREIEQTTDFKHHSLPLI QQQLQHFKNQHFEIQTTDFKHHSLPLI QQQLQHFKNQHFEIQTTDFKHHSLPLI QQQLQFFKNQHFEIQTNFKHHQLPLI AQQLQFFKNQHFEIQTNFKHHQLPLI AQQLQFFKNQFKEIEKTTDFKHHSLPLI QQQLQFFANQFKEIEKTTDFKHHSLPLI TQQLQSFHETQFKEIEKTTDFKHHSLPLI TQQLQSFHETQFKEIEKTTDFKHHSLPLI TQQLQSFHETQFKEIEKTTDFKHHSLPLI TQQLQSFHETQFKEIEKTTDFKHHSLPLI TQQLQFFANQCFIELQTNFFKHHQLPLI NEQLKSFHSKDHEGDLNYKHHFEPI SFQNRNYHIQNGANTDYKHHAFPLI QQQLQFLHADQYREIEQMKIFKHNILSI MRRFGYYSGRIFTSVDASSAIGHSLPLI QQQLRTLHADMYREIEQMKIFKNHNLSI	NF-YB Sinding NF-YA interaction RVKRIIKINDEDIKKVSSEALFL TIKRIMIADEDVDIVSNEAPVL RIKKIKADEDVRIIARCAPVU RIKKIKADEDVRIIARCAPVU RIKKIKADEDVRIIARCAPVU RIKKIKADEDV	NF-YB interaction ISLSTELFIEFHAEKAGNAA-ARKRRKI LARACEHFILELTHKGAAHA-EQKKRRI TRACEHFILELTRRAHAHA-EQKKRRI FRARCEHFILELTHRSHAHA-EEMKKRI FARACEHFILELTHRSHAHA-EEMKKRI FARACEHFILELTRSJHAH-EEMKKRI FARACEHFILELTRSJHAH-EEMKKRI FAKACEHFILELTRSJHHA-EEMKKRI FAKACEHFILELTRSJHHA-EEMKKRI FAKACEHFILELTRSJHHA-EEMKKRI FAKACEHFILELTRSJHHA-EEMKKRI FAKACEHFILELTRSJHHA-EEMKKRI FAKACEHFILELTRSJHHA-EEMKKRI FAKACEHFILELTRSJHHA-EEMKKRI FAKACEHFILELTRSJHHA-EEMKKRI FAKACEHFILELTRSJHHA-EEMKKRI FAKACEHFILELTRSJHHA-EEMKKRI FSRACEHFILELTRSJHHA-EEMKKRI SKACEHFILELTRSJHAAMAHA-EKKKHI SKACEHFILETRSJHAAMAGKKRI SKACEHFILELTRRSJHAAMAGKKRI SKACEHFILELTRSJAAMAAGMAGKKRI SKACEHFILELTRSJAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAAMAGKKRI SKACEHFILELTRSJAAMAAMAAMAAMAAMAAMAAMAAMAAMAAMAAMAAMAAM	NF-YA interaction   VKLEDL TIRAY NETDYCOFL VPTITTEEP   LQKND TIRAY NETDYCOFL VPTITTEEP   LQKND TIRAY NETDYCOFL VPTITTEEP   LQKND TIRAY NETDYCOFL VDIYPREG   LQKND TIRATIRTOY FOFL VDIYPREG   LQKND TIRATIRTOY FOFL VDIYPREG   LQKND TIRATIRTOY FOFL VDIYPREG   LQKND TIRATIRTOFFOFL VDIYPREG   LQKND TIRATIRTOFFOFL VDIYPRED
(C) DCNF-YC1 DCNF-YC5 DCNF-YC5 DCNF-YC6 DCNF-YC7 DCNF-YC19 DCNF-YC19 DCNF-YC11 DCNF-YC19 ALNF-YC1 ALNF-YC2 ALNF-YC3 ALNF-YC3 ALNF-YC5 ALNF-YC5 ALNF-YC6 DCNF-YC2 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC3 DCNF-YC4 DCNF-YC4 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF-YC5 DCNF	DNA I PVNQPSSDAEETGEPGSDAGVLTPSFPTI PQPGRCYHADQYREHEETTDFEKQRIPLI PQHLQHYLANLYREIQATTDFKHHSPLI QQQLQHFHADQYREIDQTTDFKHHSPLI QQQLQHFHADQYREIDQTTDFKHHSPLI QQQLQHFHADQYREIDQTTDFKHHSPLI QQQLQHFHADQYREIDQTTDFKHHSPLI QQQLQHFHADQYREIDQTTDFKHHSPLI QQQLQHFHYQRQEHEQAGDFKHHQLPLI QQQLQHFHYQRQEHEQAGDFKHHQLPLI QQQLQHFHYQRQEIEQYNDFKHHSPLI QQQLQHFHADQYREIDQTTDFKHHSPLI TQQLQSFHETQFKEIEKTTDFKHHSPLI TQQLQSFHETQFKEIEKTTDFKHHSPLI TQQLQSFHETQFKEIEKTTDFKHHSPLI TQQLQSFHETQFKEIEKTTDFKHHSPLI TQQLQFHANQQQEIRATTDFKHHSPLI TQQLQFHANQQEIRATTDFKHHSPLI TQQLQFHANQQEIRATTDFKHHSPLI TQQLQFHANQQEIRATTDFKHHSPLI TSPDHRMYHIRQHGARTUKHHAFPLI SPOHRNYHI	NF-YB Binding NF-YA interaction RVKRIIKMDEDIKKVSSEALFL TIKRIMMADEDVDIYSMEAPVL RIKKIMADEDVRHIAREAPVY RIKKIMADEDV	NF-YB interaction ISLSTELFIEFMREKAGNAR-ARKRRKI LARACEHFILELTHKGHAHA-DQRCRRI LTRACEHFILELTRRAHAHA-EQMKRRI FARACEHFILELTHRSHAHA-EEMKRRI FARACEHFILELTHRSHAHA-EEMKRRI FARACEHFILELTHRSHAHA-EEMKRRI FARACEHFILELTRSJIHA-EEMKRRI FAKACELFILELTRSJIHA-EEMKRRI FAKACELFILELTRSJIHA-EEMKRRI FAKACEHFILELTRSJIHA-EEMKRRI FARACEHFILELTRSJIHA-EEMKRRI FARACEHFILELTRSJIHA-EEMKRRI FARACEHFILELTRSJIHA-EEMKRRI FARACEHFILELTRSJIHA-EEMKRRI FRARCEHFILELTRSJIHA-EEMKRRI FRARCEHFILELTRSJIHA-EEMKRRI FRARCEHFILELTRSJIHA-EEMKRRI FRARCEHFILELTRSJIHA-EEMKRRI FRARCEHFILELTRSJIHA-EEMKRRI FRARCEHFILELTRSJIHA-EEMKRRI FRARCEHFILELTRSJIHA LSKACEHFILELTRSJIHA LSKACEHFILELTRSJIHA SKACEHFILELTRSJIHA SKACEHFILELTRRSJIAA SKACEHFILELTRRSJIAA SKACEHFILELTRRSJIAA SKACEHFILELTRRSJIAA SKACEHFILELTRRSJIAA SKACEHFILELTRRSJIAA SKACEHFILELTRRSJIAA SKACEHFILELTRRSJIAA SKACEHFILELTRRSJIAA SKACEHFILELTRRSJIAA SKACEHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRRSJIAA SKACHFILELTRSJIAA SKACHFILELTRSJIAA SKACHFILELTRSJIAA SKACHFILELTRSJIAA SKACHFILELTRSJIAA SKACHFILELTRSJIAA SKACHFILELTRSJIAA SKACHFILELTRSJIAA SKACHFILELTRSJIAA SKACHFILELTRSJIAA SKACHFILELTRSJIAA SKACHFILGTAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFILAA SKACHFIL	VKLEDLRTAITGHSPTAOFILDCLPETSK IKKEDTAAVLTKINHYDFLAESHKDIGG LQKNDTAAVLTKINHYDFLAESHKDIGG LQKNDTAAATTRIDYFOFLYDIYPREEG LQKNDTAAATTRIDYFOFLYDIYPREEG LQKND

Fig. 1. (continued).

-KMISCEAPLYFAKACELFIQQLTYRSYKYS-YQAKKRTLQKDD

## 2.5. Expression profiling

DcNF-YC4

The expression level of NF-Y genes in different tissues such as flower buds (SRX2251519), pollinia (SRX2938662), leaf (SRX2251517), stem (SRX2251516) and root (SRX2938667) was calculated by using the number of hits obtained in SRA BLAST of CDS sequences of the putaidentified genes (https://blast.ncbi.nlm.nih.gov/Blast.cgi? tively PROGRAM=blastn&PAGE\_TYPE=BlastSearch

HRQAGIYSGHHHG----KKPCPNSLPLSRIKKIHKQSGEDY-

&BLAST\_SPEC=SRA&LINK\_LOC=blasttab#i). These hits were used to estimate the RPKM values in different tissues for each gene (Mortazavi et al., 2008) and a heat map was developed using ClustVis visualizing tool with correlation clustering of the genes (https://biit.cs.ut.ee/clust vis/).

## 3. Results

In Dendrobium catenatum, 27 sequences were identified and classified into three sub-families as five in NF-YA, 10 in NF-YB and 12 NF-YC. The classification of the protein sequences was performed with the help of conserved domain searches in NCBI CDD. The DcNF-YA protein sequences showed identity with smart00521 and pfam02045 which had similarity with NF-YA domain. Similarly, DcNF-YB and DcNF-YC sequences showed similarity with PF00808 in Pfam database but showed variability in CDD search, where DcNF-YB sequences had similarity with pfam00808 while DcNF-YC sequences matched with cl30738 in NCBI CDD. Except in case of DcNF-YC1, it showed pfam00808 as domain identification feature but the sequence was shifted to NF-YC because of its sequence similarity with AtNF-YC3 and VpNF-YC1. The DcNF-Y sequences were further confirmed with the help of related orthologous sequences of Vanilla planifolia and Arabidopsis thaliana (Supplementary Table 1).

-IYTAYKATEYFDFLYEMYTASNA

The protein sequences of three NF-Y sub-families were aligned separately to determine the degree of conservation in the domain region and this revealed the presence of DNA binding domain and a sub-unit binding domain. DcNF-YA proteins had two interaction domains and one DNA binding domain, which were separated by a linker. DcNF-YB



Fig. 2. The structural placement of conserved motifs in DcNF-Y proteins.

proteins had a DNA-binding domain, a NF-YA interaction domain, and a NF-YC interaction domain. DcNF-YC proteins had four domains: two NF-YA interaction domains separated by NF-YB interaction domain and the DNA-binding domain was present in the first NF-YA interacting domain (Fig. 1).

The distribution and arrangement of motifs in DcNF-Y proteins was assessed by MEME server (Fig. 2). DcNF-YA protein sequences were marked by the predominant presence of motif 1 and motif 7 and additionally, motif 10 was observed in DcNF-YA1 and DcNF-YA2. DcNF-YB is characterised by presence of motif 1, motif 2, motif 3, motif 5 and motif 8 while motif 1, motif 2 and motif 4 were conserved in most of DcNF-YC sequences except DcNF-YC1 where only motif 1 was present. A phylogenetic relationship was established between *Arabidopsis thaliana*, *Dendrobium catenatum* and *Vanilla planifolia*. The tree was categorised into three sub-families: NF-YA, NF-YB and NF-YC. Also, protein sequences of *D. catenatum* showed closer relation with *V. planifolia* than with *A. thaliana* (Fig. 3).

The CDS length of the *DcNF-Y* genes ranged from 336 bp (*DcNF-YC3*) to 1302 bp (*DcNF-YA1*) as given in Table 1. The protein length varied from 111 (DcNF-YC3) to 433 (DcNF-YA1) amino acids. DcNF-YAs were generally longer than others with an average length of 322aa. The

average molecular weight was 22,757.40 Da with range varying from 12,214.21 Da to 48,768.39 Da. The average value of aliphatic index (AI), isoelectric point (pI) and GRAVY across three sub-families was 67.51, 7.2 and -0.57, respectively (Table 1).

The interaction network between the NF-Y proteins showed that DcNF-YB9 interacts with DcNF-YA2, DcNF-YA4, DcNF-YC6, DcNF-YC10 and DcNF-YC12 while DcNF-YB5 interacts with DcNF-YC6, DcNF-YC10 and DcNF-YC12 suggesting that the formation of complex protein interactions could play an important role in different developmental processes (Fig. 4).

*DcNF-YA* had four introns except in case of *DcNF-YA1* and *DcNF-YA3* which had 5 introns each (Fig. 5). *DcNF-YB* genes were intron-less except *DcNF-YB1*, *DcNF-YB2* and *DcNF-YB3* which had 4 introns and *DcNF-YB4* had 2 introns. All of *DcNF-YC* were intron-less with exception of *DcNF-YC6* where a single intron was found. Moreover, most of the introns were present in zero phase pointing towards the conserved nature of the genes.

A total of 95 unique cis-regulatory elements were identified across three NF-Y sub-families in *D. catenatum* where 5, 14 and 11 unique elements were found in *DcNF-YA*, *DcNF-YB* and *DcNF-YC*, respectively (Fig. 6a). A total of 39 elements such as ERE, CAAT-box, W box, TCA-



NF-YA

Fig. 3. Phylogenetic relationship between NF-Y proteins of Arabidopsis thaliana, Dendrobium catenatum and Vanilla planifolia.

Table 1	
Physical and chemical properties of DcNF-Y proteins.	

DcNF-YA1130243348,768.399.6959.157DcNF-YA2104434738,242.549.1352.159.39DcNF-YA390930233,420.499.359.9757.28DcNF-YA459119621,332.76.7961.9958.83DcNF-YA5100233336,438.039.3141.8562.1DcNF-YB163621123,219.16.9249.6564.79DcNF-YB255218320,146.988.6948.3258.2	GRAVY
DcNF-YA2104434738,242.549.1352.159.39DcNF-YA390930233,420.499.359.9757.28DcNF-YA459119621,332.76.7961.9958.83DcNF-YA5100233336,438.039.3141.8562.1DcNF-YB163621123,219.16.9249.6564.79DcNF-YB255218320,146.988.6948.3258.2	-0.851
DcNF-YA390930233,420.499.359.9757.28DcNF-YA459119621,332.76.7961.9958.83DcNF-YA5100233336,438.039.3141.8562.1DcNF-YB163621123,219.16.9249.6564.79DcNF-YB255218320,146.988.6948.3258.2	-0.807
DcNF-YA459119621,332.76.7961.9958.83DcNF-YA5100233336,438.039.3141.8562.1DcNF-YB163621123,219.16.9249.6564.79DcNF-YB255218320,146.988.6948.3258.2	-0.817
DcNF-YA5100233336,438.039.3141.8562.1DcNF-YB163621123,219.16.9249.6564.79DcNF-YB255218320,146.988.6948.3258.2	-0.703
DcNF-YB1 636 211 23,219.1 6.92 49.65 64.79   DcNF-YB2 552 183 20,146.98 8.69 48.32 58.2	-0.631
DcNF-YB2 552 183 20,146.98 8.69 48.32 58.2	-0.565
	-0.676
DcNF-YB3 540 179 19,492.81 5.5 59.88 59.5	-0.721
DcNF-YB4 522 173 20,117.26 6.44 53.96 85.14	-0.308
DcNF-YB5 672 223 24,618.27 5.98 41.42 64.3	-0.635
DcNF-YB6 648 215 23,330.74 8.77 66.98 49.19	-0.795
DcNF-YB7 603 200 20,746.88 7.69 40.77 49.75	-0.698
DcNF-YB8 651 216 22,598.89 5.97 48.5 46.16	-0.707
DcNF-YB9 549 182 19,728.98 6.22 48.06 58.23	-0.729
DcNF-YB10 477 158 18,105.76 9.24 55.28 70.38	-0.679
DcNF-YC1 462 153 16,650.02 5.59 59.73 80.46	-0.423
DcNF-YC2 384 127 13,731.79 9.3 47.62 85.98	-0.136
DcNF-YC3 336 111 12,214.21 8.5 49.28 88.83	-0.073
DcNF-YC4 342 113 12,740.04 9.42 41.04 78.5	-0.220
DcNF-YC5 486 161 18,175.36 4.5 43.82 71.55	-0.588
DcNF-YC6 615 204 23,559.23 9.88 55.26 73.19	-0.546
DcNF-YC7 513 170 19,528.95 5.45 55.06 70.71	-0.655
DcNF-YC8 510 169 19,373.79 5.45 58.94 71.12	-0.622
DcNF-YC9 519 172 19,693.21 5.65 50.85 76.16	-0.540
DcNF-YC10 384 127 15,013.04 5.48 33.69 83.78	-0.586
DcNF-YC11 654 217 23,465.35 4.98 53.05 68.89	-0.394
DcNF-YC12 825 274 29,997.05 5.28 65.07 73.47	-0.322



Fig. 4. String based interaction network between DcNF-YA, DcNF-YB and DcNF-YC proteins.

element, WUN-motif etc., were common to all three *NF-Y* sub-families in *D. catenatum.* The location of some of these elements on the promoter region of the genes was visualized in Fig. 6b. These cis-regulatory elements were divided into four groups: light, stress, hormone and growth & development. Light associated cis-regulatory elements such as G-box, Box 4, GA motif, TCT-motif, GATA motif, MRE, GA motif and many others were present across *NF-Y* gene family with G-box being the most abundant. Beside these, hormone responsive elements such as ABRE, CGTCA-motif, GARE-motif, TGACG-motif, TGA-element, P-box, etc. were also present. ABRE related to abscisic acid was the most predominant cis-regulatory motif in *DcNF-Ys*. However, cis-regulatory elements (GCN4\_motif, HD-Zip 1, RY-element) related to growth and development were least in number (Fig. 6c).

Expression levels between different tissues such as root, stem, leaves, pollinia and flower bud was assessed across *DcNF-Y* genes (Fig. 7). It was observed that *DcNF-YA2* and *DcNF-YC3* showed high expression in stem while 11 out of 27 *DcNF-Y* genes showed high transcript levels in the

root tissue. *DcNF-YB7*, *DcNF-YB9* and *DcNF-YB10* were more prominent in roots. *DcNF-YC11* had the highest expression in leaves. Most genes expressed in pollinia belong to *NF-YB* and *NF-YC* where about 70% of *DcNF-YBs* had high expression levels in pollinia. Their expression levels were moderate in flower buds signifying the role of these gene in reproduction. This variable expression of the *DcNF-Ys* in different tissues of *Dendrobium catenatum* suggests that this gene family play profuse role in different developmental pathways during plant growth.

## 4. Discussion

Nuclear factor-Y gene family is a vital transcription factor family having prominent role in embryogenesis, root formation, stress tolerance and many other developmental processes in plants. Due to the enormous importance of this family, a study was conducted to identified and characterised these genes in an economically important orchid plant, Dendrobium catenatum. The 27 NF-Y genes were identified in Dendrobium catenatum. The multigene nature of the family has also been reported in many other plants such as Citrus grandis (Mai et al., 2019), Manihot esculenta (He et al., 2019), Vanilla planifolia (Arora et al., 2020) and many others. The proteins were sub-grouped into three sub-families; NF-YA (5), NF-YB (10) and NF-YC (12) on the basis of specific conserved domains. Similar observations have been made in Hordeum vulgare (Panahi et al., 2019) and in Glycine max (Quach et al., 2015). The result of multiple sequence alignment in D. catenatum is in line with the previous published reports on Camellia sinensis (Wang et al., 2019), Juglans regia (Quan et al., 2018) and Prunus persica (Li et al., 2019) which shows the presence of DNA binding and NF-Y interacting domains. Several reports have indicated that all the three sub-families i.e. NF-YA, NF-YB and NF-YC as identified by their conserved domains that interact, form complex and bind with DNA at CCAAT site of the promoter region (Myers and Holt III, 2018). The conserved organizations of the specific domains in each subfamily suggest that these transcription factors remained highly conserved during plant evolution thus contributing to their vital developmental roles (Chen et al., 2020).

Evolutionary analysis between NF-Y proteins of *Arabidopsis thaliana*, *Vanilla planifolia* and *Dendrobium catenatum* revealed that these proteins cluster into three subfamilies i.e. NF-YA, NF-YB and NF-YC. Moreover,



Fig. 5. Gene structure organization of DcNF-Y genes constructed by GSDS.



Fig. 6. a. Venn diagram depicting the presence of common and unique cis-regulatory elements (CREs) in the 1.5 kb promoter region. b. Positional visualization of twelve CREs in the promoter region of the respective genes. c. Graphical representation of the numerical variation between light, hormone, growth and stress responsive cis-regulatory elements in DcNF-Ys.

DcNF-Y proteins are more similar with VpNF-Y counterparts than with AtNF-Y sequences. Such relationships have been observed in cucumber where proteins from dicot cucumber and *Arabidopsis* were relatively more similar than with monocot rice (Chen et al., 2020). NF-YB was further classified into LEC-1 and non-LEC1 groups as found in *Brachypodium* (Cao et al., 2011) and tea (Wang et al., 2019). LEC group contains AtNF-YB6, AtNF-YB9, VpNF-YB5, VpNF-YB6 and DcNF-YB5. The members of LEC group have seed specific role as observed in both *Arabidopsis* and *Vanilla* (Petroni et al., 2012; Arora et al., 2020).

According to earlier studies, *NF-YA* genes had 3–6 introns whereas variations were reported in *NY-YB* and *NF-YC* (Feng et al., 2015; Wang et al., 2018; Chen et al., 2020). The similar observations have been made in this study where 4–5 introns were present in *DcNF-YA*. Most of the *DcNF-YB* and *DcNF-YC* were intron-less which is also in accordance with

reports on chickpea where 11 *NF-YBs* and 7 *NF-YCs* were intron less (Chu et al., 2018). The comparable observation has also been made in banana (Yan et al., 2019), cucumber (Chen et al., 2020) and apple (Qu et al., 2021) where majority of the *NF-YB* and *NF-YC* genes had no introns. The similar organization of gene structure in indications towards plausible conservation of NF-Y gene family during the evolution of plant history.

A total of 95 cis-regulatory elements were found in the promoter region of *DcNF-Y* genes. The light responsive elements were the most abundant ones followed by hormone responsive elements. Stress responsive elements such as ARE, LTR, MBS, TC-rich repeats and WUNmotifs were present in *DcNF-Y* and similar observations have been made in case of cucumber suggesting their role in mitigating stress conditions (Chen et al., 2020). The presence of hormonal responsive elements such



■ Hormone responsive elements ■ Growth and development related elements ■ Light responsive element ■ Stress responsive elements

Fig. 6. (continued).



Fig. 7. Expression analysis of DcNF-Y genes across different tissues such as flower bud, pollinia, leaf, stem and root.

as ABRE, ERE, CGTCA-motif, TCA-element, TGA-element, GARE-motif etc. in *D. catenatum* is in accordance with the results obtained in the study done on cucumber (Chen et al., 2020). G-box element was the most common light responsive elements and similar results have been reported in apple (Qu et al., 2021).

Expression of NF-Y genes was studied in various tissues DcNF-YA3, DcNF-YB10, DcNF-YC2 and DcNF-YC4 had root specific expression. Similarly, in cucumber, CsaNF-YA3 and CsaNF-YB13 transcripts were abundant in roots (Chen et al., 2020). MdNF-YA9, MdNF-YB8, MdNF-YB18 and MdNF-YB19 had high expression in roots of Malus domestica (Qu et al., 2021). In Brassica napus, BnNF-YA1, BnNF-YA2, BnNF-YA3, BnNF-YB14, BnNF-YC4 and BnNF-YC5 had high transcript levels in root (Liang et al., 2014). Also, Vanilla planifolia and Triticum aestivum showed similar observations where NF-YA transcript levels were high in roots (Arora et al., 2020; Stephenson et al., 2007). DcNF-YB6 and DcNF-YB7 homologous to VpNF-YB4 showed moderated expression in roots and similar observation has been made in the previous study. DcNF-YC3, DcNF-YC8 and DcNF-YC12 were expressed in stem and this could be corroborated with the fact that MaNF-YC3 showed strong expression in the stem of banana (Yan et al., 2019). DcNF-YA2 had high level of expression in stem tissue. This was in line with the study on Brassica napus where BnNF-YA3 was highly expressed in stem (Liang et al., 2014). DcNF-YB2 and DcNF-YB3 showed expression in the floral buds of D. catenatum. Similar observations were made in case of cucumber where CsaNF-YB9 expression was in male flowers (Chen et al., 2020). The high expression levels of BnNF-YB10 and BnNF-YB11 in flowers of B. napus were reported (Liang et al., 2014). Also, BdNF-YB6 of Brachypodium distachyon and HvNF-YB1 of Hordeum vulgare were reported to increase flowering in Arabidopsis (Cao et al., 2011; Liang et al., 2012). Also, RcNF-YB9 expression was more prominent in male flowers in Ricinus communis (Wang et al., 2018). This could help in functional analysis of NF-Y members in plants where flowering trait is of commercial importance. The expression of DcNF-YC6, DcNF-YC7 and DcNF-YC12 were observed both in vegetative and reproductive tissues and it was in line with the study on peach where PpNF-YC1 was present both in vegetative tissues and reproductive tissues (Li et al., 2019). This suggest showing that the NF-Y genes might play different roles during development of plant.

## 5. Conclusions

The present study categorically identifies and characterises members of the *NF-Y* gene family in *Dendrobium catenatum*. Twenty-seven DcNF-Y proteins were identified and categorised into three sub-families, NF-YA, NF-YB and NF-YC, based on presence of specific conserved domains and phylogenetic analysis. Variable expression levels of *DcNF-Y* genes in different tissues indicated the diverse potential of these transcription factors in plant growth and development which can be further functionally tapped for the genetic improvement in this economically important orchid species.

## Funding

JKS is grateful to Council of Scientific and Industrial Research (CSIR), India for research support No. 38(1443)/17/EMR-II. DG is grateful for Senior Research Fellowship (File No. 09/135(0809)/2018-EMR-I) by CSIR. We are also grateful to Department of Science and Technology, Government of India for partial financial support under Promotion of University Research and Scientific Excellence (PURSE) grant scheme.

## Authors' contributions

DG performed the experimental procedure, compiled the results and drafted the manuscript. JKS envisioned the project, designed the experiment and revised the manuscript.

## **Declaration of Competing Interest**

There is not conflict of interest between authors.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.plgene.2022.100365.

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